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CLASS BOOK

OF

BOTANY.

BEING OUTLINES OF

THE STRUCTURE, PHYSIOLOGY AND CLASSIFICATION

OF

PLANTS.

WITH A FLORA

OF ALL PARTS OF

THE UNITED STATES

AND

CANADA.

BY ALPHONSO WOOD, A.M.

> He spake of trees, from the Cedar of Lebanon even unto the Hyssop that springeth out of the wall.—1 KINGS, iv. 33.
>
> Consider the lillies of the field—even Solomon, in all his glory was not arrayed like one of them.—MATTHEW, vi. 28, 29.

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WOOD'S
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OF
BOTANY.
PART I., II., & III.

PUBLISHERS' NOTE.

In consequence of the urgent request of many Teachers, the Publishers have concluded to print—*in advance* of the completion of Professor Wood's Entire Work—the *first three parts,* which will be followed by the remaining portions as speedily as possible. Teachers introducing this part of the work, shall be furnished with the remainder in a bound Volume at a price bearing the same proportion, to the value of the whole Book when completed.

PREFACE.

The Class-Book of Botany was first offered to the student in 1845. It was originally prepared with immediate reference to the wants of the author's own pupils, with scarcely a hope of approval from the community beyond. The event, however, proved that the wants of his own pupils were precisely the same as those of myriads of others; and the use of the book, notwithstanding its numerous imperfections, soon became general.

The lapse of fifteen years has done much to develop not only the knowledge of our native Flora, but of the science of Botany in general; and materials for the revision of our whole work have indefinitely accumulated. In this revision, which seems to be demanded not less by the growing appreciation of scientific studies as a means of intellectual and moral discipline, than by the progress of the science itself, we have still confined ourselves to the limits of *a single volume*, and sternly resolved against any essential enlargement, except such as the increased territory of our Flora requires. This we have done with direct reference to the *convenience* and the *means* of the thousands of youths who will still enter upon this delightful pursuit, and make their text-book their *vade-mecum.* The labor expended in this condensation will be appreciated by few, and those few, while they justify the motives, will regret the necessity.

The limit of our Flora in this new series has been much extended. It now embraces the territory lying East of the Mississippi River with the exception of the Southern Peninsula of Florida, and South of the Great Lakes and the River St. Lawrence. The States bordering upon the western shores of the Mississippi, although not *strictly* included, are *essentially* so, as well as those provinces of Canada upon the northern shore of the St. Lawrence. This Class-Book is, therefore, now professedly adapted to the student's use from Quebec to New Orleans and from St. Pauls to St. Augustine.

The southern peninsula of Florida is neglected in consequence of the author's inability to visit that region hitherto. During his extended tour southward in 1857, the Seminole war rendered the route to the

Everglades unsafe, or at least undesirable. The species omitted are generally unknown northward of Key West. Students at Mecanopy, Ocala, to St. Augustine, will scarcely miss them; but should they do so, they will confer a grateful favor by contributing specimens of such to the author.

That every species of native plant in this extensive region is accurately defined, or even noticed, we cannot presume; yet this has been our aim; and as in the former series, so here, we have distrusted every source of information except that of our own personal inspection. Therefore, into nearly every section of this territory, from the St. Lawrence and the Lakes to the Gulf, and from the Sea-Coast to the Great River, the author has made repeated excursions in delighted converse with the vegetable world.

Together with the plants of spontaneous growth which constitute our proper Flora, we have included in our sketches also our exotic Flora; that is, all those plants which seem to us to have attained a general cultivation in this country, either as useful, curious, or ornamental. By this accession, learners in the city, as well as in the country, may be supplied with subjects for illustration and for practice in botanical analysis; and all with the means of acquainting themselves with the beautiful tenants of their own fields, gardens, and conservatories.

From the multiplication of species and genera we have studiously refrained, believing that our books already contain more than Nature will warrant. In the case of any doubtful specimen, which might have served as the basis of a new species, or possibly genus, (had this been our aim), we have always inclined rather to the extension of the limits of some kindred group for its reception, having less apprehension of error in this direction than in the opposite, with all due regard for the permanence of true species. The same principle has compelled us to disallow the claims of many reputed species of the best authors.

In the sequence of the Natural Orders, we have, in common with all recent American authors, mainly adopted the arrangement of De Candolle,—an arrangement seen, in part, in the 'Flora of the State of New York,' by Dr. Torrey. It commences with those Orders supposed to be of the higher rank in organization, and proceeds gradually to the lower, regarding the completeness of the flower and the distinctness of its parts as the general criterion of rank.

Tables of analysis by the dichotomal method were first in the Class-Book applied to the genera of plants, and introduced into general use. They are now regarded as indispensable, and have been adopted into their Floras by nearly every subsequent author. In the present new series, we have greatly modified, extended, and improved this system, adapting it to the analysis of *Species* as well as of Orders and Genera. By means of this addition, our Flora is now adapted to *class exercises in analysis throughout, from the Grand division to the Species*—an im-improvement which will be duly appreciated by the practical teacher.

An analytical Key to the Orders, mainly artificial, more simple than any hitherto constructed by us, founded, as in the previous edition, almost solely upon characters taken from the flowers and leaves (not fruit), will readily conduct the student to that Order where any given flowering specimen may belong. Next, under the Order, a table of the utmost simplicity, analyzes the Genera, *mostly* in such a way as to do but little violence to their natural affinities. Lastly, under the Genus (when large enough to require it) another table conducts to the species in groups of twos or threes, which groups are instantly resolved by a brief *diagnosis in italics* catching the eye in some part of the description which follows.

The limited space allowed us in the Flora compels us to use very sparingly illustrative engravings in this part of our work, which occasions us less regret considering the copiousness of illustration in the scientific treatise in the former part. Those engravings are designed partly with reference to the Flora, where frequent references will be found. The few which we have adopted in the Flora, are prepared with reference to the deficiencies of the former part. In other words those which have no illustrative figure in the former treatise are generally furnished with one or more in the Flora. Throughout the work, these are mostly from original sketches and drawings on wood by the author's own hand. Others are copied from Lindley, Henfrey, Peyer, &c.

In addition to those colaborers in Botany, whose invaluable aid is acknowledged in former editions, namely Dr. Edward E. Phelps, Dr. James W. Robbins, Dr. Joseph Barratt, Dr. Albert G. Skinner, Mr. I. A. Lapham, Dr. Truman Ricard, Dr. H. P. Sartwell, Dr. John Plummer, Dr. S. B. Mead, Mr. S. S. Olney, &c., we have now to mention with grateful acknowledgments other names of equal merit.

Dr. Josiah Hale of Alexandria, La., has sent us a suit of specimens, well nigh representing the entire Flora of that State.

Dr. A. W. Chapman of Apalachicola, Fla., presented us with many of the more rare plants of Florida, on the occasion of our recent visit to his own familiar walks.

Dr. H. A. Mettauer of Macon, Ga., has made contributions of great value from that district, and from the vicinity of Tallahasse and St. Marks, Fla., with many critical notices and observations on the Flora of those States.

Prof. William T. Feay, M.D., and Prof. Thomas G. Pond, both of Savannah, Ga., have sent almost the entire Flora of that State, with copious original notes and observations, such as result only from the most extensive and accurate investigation.

Miss Sarah Keen of Bainbridge, Ga. (now of Mariana, Fla.), has also sent an herbarium of beautiful specimens prepared by her own and her sister's hands. To her, as well as to the gentlemen last mentioned, the author is also indebted for every kind hospitality and encouragement during a protracted herborizing tour along our southern coasts.

Mr. William Wright of Bainbridge, and Prof. N. H. Stuart of Quincy, Florida (since deceased), also contributed to the consummation of our work by many facilities afforded us in our laborious researches in their respective precincts, and by the shelter of their hospitable mansions.

To Rev. Dr. Curtis of Hillsborough, N. C., and to Rev. Dr. Bachman of Charleston, S. C., we are indebted for the free use of their very complete herbaria, during our sojourn in their respective cities; and Mr. S. B. Buckley, recently of Yellow Springs, Ohio, has afforded us similar facilities through his rich collection.

Dr. Cousens generously supplied us with the plants of the State of Iowa. His name often appears in our pages.

Dr. George Engelmann, of St. Louis, has also favored us with the free use of his admirable monograph of the genus Cuscuta, and with many important notes in MS. on other difficult genera in our Flora, especially on the Euphorbiaceæ. Our entire collection of specimens belonging to this Order was, by his kind permission, submitted to his inspection and determination.

The Rev. Chester Dewey, D.D., of Rochester, N. Y., the venerable pioneer in American Caricography, has placed us and our readers under renewed obligations by additional contributions to the genus Carex, rendering it complete for the extended territory of our present Flora.

Communications containing specimens, critical notices or corrections, or soliciting information, will always, as heretofore, be acceptable.

TERRE HAUTE FEMALE COLLEGE (Indiana), May, 1860.

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INTRODUCTION.

CHAPTER I.

LEADING PRINCIPLES OF SCIENCE:—MENTAL AND MORAL DISCIPLINE ITS AIM AND END.

1. **Plants as related to Man.** The vegetable kingdom maintains towards man several important relations. Besides its obvious utility as the source of his food, shelter, clothing and medicine, it furnishes an exhaustless field for interesting and disciplinary study.

2. **Proof that Nature is related to Mind.** This remark is commonplace. But the fact stated is neither a necessity nor accident. Since the phenomena of Nature are ordained subject to the cognizance of the human understanding while yet their depths are unfathomable by it, it is evident that God made them for each other. It is certainly conceivable that He might have ordained otherwise.

3. **Illustration.** The phenomena of vegetation, or of nature in general, might have been all simple and uniform, thus awakening no curiosity, presenting no motive for study. Or on the other hand, they might have involved plans so intricate as to defy all efforts of the mind in their investigation. In this case, as in the former, the mind and nature would have remained for ever estranged.

4. **The study of Nature successful.** But an intermediate course hath seemed good to an All-wise and Beneficent Creator. The works of His Hand are commensurate with the powers of the understanding. We study them not in vain. Step by step His plans are unfolded; and research, although never reaching the goal, yet never wearies, nor fails of its appropriate reward.

5.—**Pleasurable.** Hence the study of nature, through this beautifully adjusted relation, becomes a source of the purest pleasure, being ever accompanied by fresh discoveries of truth in the plans and operations of a sublime Intelligence.

6.—**Disciplinary.** But a higher purpose than present pleasure is accomplished by this means, namely, discipline. Entering life as a mere germ, the soul expands into intelligence and virtue through the teachings of surrounding objects and influences. In this good work the beauty, purity and wisdom displayed in the vegetable world bear a full share. These invite to investigation; and their tendency is to impress upon their votaries the characteristics of their own sincerity and loveliness.

7. **Creative Wisdom never works in vain**, nor merely in sport. Even the flying cloud which now passes over the sun has its mission; the forms which it assumes, and the colors, were each necessary and divinely appointed for that special purpose. The hills and valleys, which seem scattered in accidental confusion, have received each their contour and position by design, according to the ends foreseen. Consequently, each stone or mineral composing these hills was also the work of special design, as to its magnitude, form and place.

8. No accident or caprice in Nature. Much more in the living kingdoms of nature may we look for an adequate purpose and end accomplished by every movement and in every creature of the Divine hand. Each species is created and sustained to answer some worthy end in the vast plan; and hence no individual, animal or plant is to be regarded in science as insignificant, inasmuch as the individual constitutes the species. Nor is accident or caprice to be found in the form of the leaf or the color of the flower. There is for each a special reason or adaptation worthy of unerring wisdom.

9. Object of natural Science. In the study of nature we are therefore concerned in reasons and ends as well as in forms and appearances. That investigation which ceases contented with the latter only is peurile. It may amuse, but can scarcely instruct, and can never conduct to that purest source of the student's enjoyment, namely, the recognition of Intelligence by intelligence.

10. Design, a settled principle in Science. The end or purpose, it is true, is not always as easily discerned as the form and fashion are. In a thousand instances the end is yet inscrutable. Nevertheless it is now a settled principle of science that there is an end—a purpose—a reason, for every form which we contemplate; and the adaptation to that end is as beautiful as the form itself. That the tendril of the vine and the runner of the strawberry were happily adapted to a special purpose is readily admitted; for that purpose is immediate and obvious to all. Let us not then say that the spine, the stipule, or the varying tints of the rose, were made merely in caprice, their uses being less obvious in the present state of our knowledge.

11. Design, as distinguished from "Typical Forms." In addition to this sequence of cause and effect in nature, disclosing the Infinite Designer in all things, as early taught by Paley in his "Natural Theology," another class of principles more recently developed are shown by the author of "Typical Forms" (McCosh), to indicate with a still clearer light the thoughts of the Omniscient Mind in the operations of nature. A single observation often suffices for the discovery of *design*, as in the down of the thistle, by means of which the seed is wafted on the winds to flourish in distant lands. But a *typical form* or *plan* requires a long series of observations for its discernment.

12. Typical Forms illustrated. The scientific world were slow to learn that the numerous organs of plants so diversified in form and use are all modeled from a single type, one radical form, and that form, the *leaf!*

13. Results. This interesting doctrine, now universally admitted, sheds a new light upon nature, making it all luminous with the Divine Presence. It brings the operations of the Great Architect almost within the grasp of human intelligence, revealing the conceptions which occupied His mind before they were embodied in actual existence by His word.

14. Graduated Forms. Again, by continued observation, the principle of graduated forms, allied to the last, appeared as another grand characteristic of nature. This principle implies that while natural objects vary to wide and seemingly irreconcilable extremes, their differences are never abrupt, but they pass by insensible gradations and shades from species to species in a continuous series.

15. Illustration. Thus in *magnitude*, although the tiny moss is far removed from the gigantic oak, yet a series connects them representing every imaginable intermediate grade in size. So in *number*, from the one-stamened saltwort to the hundred-stamened rose, there is a connecting series, representing every intervening number. Moreover, in *form* and *figure*, we pass from the thread-leafed pine to the broad-leafed poplar through a series of every intermediate degree of leaf-expansion;

and from the regular-flowered crowfoot to the distorted monks-hood by a series graduated in like manner.

16. NATURA NON SALTUS FACIT, said Linnæus, in evident allusion to this beautiful principle, which will constitute one of the most interesting themes of botanical study.

17. ACCOMODATED FORMS or organs is a phrase applied to another principle in the Divine plan, the reverse of the first. This principle appears in the adaptation of different organs in different species to one common use; of which there are many familiar

18. EXAMPLES. Thus, the slender vine requires support. Now it throws out a tendril for this very purpose, grasping whatever object it may reach, as in the grape. Again, the prolonged leaf-stalk answers the same end, as in Clematis. Again, the supple stem itself, by its own coils supports itself, as in the hop; and, lastly, adventitious rootlets in the ivy.

19. ANOTHER ILLUSTRATION. Reproduction is the general office of the seed; but this end is also accomplished, in different species, by nearly every other organ, by buds, bulblets, bulbs, tubers, cuttings, scions, and even leaves.

20. ANOTHER. This principle is also traced in the nutritious deposits of plants, which are generally made in the fruit; but often the root serves as the reservoir instead, or even the stem. And in case of the fruit, the rich deposit is now found in the pericarp of the peach, the calyx of the apple, the receptacle of the strawberry, the cotyledons of the almond, the bracts, flower-stalks, &c., of the pine-apple. Thus God's boundless resources of skill can accomplish either one purpose in a thousand different ways, or a thousand different purposes by a single organ.

21. ARRESTED FORMS. This principle, demanding a wider range of generalization than either of the foregoing, we state rather as a hypothesis, that the student may hereafter test its probability by his own observations. The flowering plants which clothe the earth in such numbers, constituting the apparent vegetable world, are in truth but a minor part of it in respect to numbers. Numerous tribes, of lower rank, embracing thousands of species, reach far down the scale, beyond the utmost limits of the microscope. Now a principle of analogy seems to pervade these ranks, called the principle of arrested forms, binding all together in one consistent whole, proving that for the vast realm of vegetation there was but one plan and one origin.

22. THE HYPOTHESIS STATED. The successive tribes of vegetation, beginning with the lowest, have each their type or analogue in the successive stages of embryonic growth in the highest tribe.

23. MORE EXPLICITLY: the flowering plant, in the course of its growth from the pollen grain to the completed embryo, passes necessarily through a series of transient forms. Now, suppose the development of the plant *arrested* at each of these stages, so that these transient forms become permanent, we should have a series of organisms analogous to the various tribes of Flowerless Plants; the Protococcus, *e. g.*, an arrested pollen grain; the Oscillaria, an arrested pollen tube; and so on up to the Marsillea, whose organization answers to that of the full-formed embryo of the flowering plant. Thus we might truly say of the lower plants that they are the *arrested forms* of the higher.

24. INDIVIDUALITY OF THE PLANT. The plant is both material and immaterial. Its form and substance is the material, its life the immaterial. The material commences existence as a single cell, and is ever changing. The immaterial gives to that cell its individuality, and fixes inevitably its law of development, so that it must grow up to become such a plant as it is, and by no possibility any other.

25. ILLUSTRATION. The embryonic cell of a rose may not differ *materially*, in the

least, from that of the grape: but the individuality of each is widely different. This principle in the one will make it a rose; in the other, a grape. Individuality can not be predicated of a stone.

26. Life and death are equally predicated of the plant. The latter follows close upon the former, with unequal, inevitable step, and soon disputes possession in the same living fabric. The plant both lives and dies at once. Life passes on from cell to cell, and in the parts which it has abandoned dissolution and decay are soon manifest. Thus the whole existence of the *individual* is a contest. Life advances, death pursues, and ultimately triumphs. But not so in the *species*. Securely transferred to the seed, the living immaterial plant mocks the destroyer, and begins its career anew, multiplied a hundred fold.

27. The seed of the plant is its redemption. Through this appointment, the conquest of death is apparent, while the triumph of life is real. In the "grain of mustard" there is literally a *faith*—an energy which will raise it from the dust, "a tree." Yet, as in the wheat and all other seed, "it shall not be quickened except it die." Hence,

28. Plants may teach us lessons in sacred things. While we study the facts and the forms of the vegetable world, we should also aim to learn the purposes accomplished, and the great principles adopted in its creation. We should also learn to recognize here the tokens (too long overlooked) which declare that nature sympathizes with humanity in the circumstances of the Fall, the Redemption, and the Life. Such study alone is adapted to acquaint us with the thoughts of the intelligent Creator, and to discipline aright the mind which was created in His image.

29. Botany combines pleasure with improvement. It conducts the student into the fields and forests amidst the verdure of spring and the bloom of summer; to the charming retreats of Nature in her wild luxuriance, or where she patiently smiles under the improving hand of cultivation. It furnishes him with vigorous exercise, both of body and mind, which is no less salutary than agreeable, and its subjects of investigation are all such as are adapted to please the eye, refine the taste, and improve the heart.

CHAPTER II.

THE DEPARTMENTS OF THE STUDY.

30. Three great departments in nature are universally recognized, commonly called the mineral, vegetable, and animal kingdoms. The first constitutes the *Inorganic*, the other two the *Organic World*.

31. A mineral is an inorganic mass of matter, that is, without distinction of parts or organs. A *stone*, for example, may be broken into any number of fragments, each of which will retain all the essential characteristics of the original body, so that each fragment will still be a stone.

32. A plant is an organized body, endowed with vitality but not with sensation, composed of distinct parts, each of which is essential to

the completeness of its being. A *tulip* is composed of organs which may be separated and subdivided indefinitely, but no one of the fragments alone will be a complete plant.

33. **Animals**, like plants, are organized bodies endowed with vitality, and composed of distinct parts, no one of which is complete in itself, but they are elevated above either plants or minerals by their power of perception.

34. **These distinctions**, long since suggested by Linnæus, the founder of botanical science, are perfectly obvious and definite in the higher grades of the animal and vegetable kingdoms. But in descending the scale, we recognize a gradual approach, in both, to inorganic matter, and consequently to each other, so that in the lowest forms of life all traces of organization are lost to our perception, and the three kingdoms of nature, like converging radii, apparently meet and blend in a common centre.

35. **The position of the plant-world in rank** and office is intermediate. While inferior to the animal in respect to perception and instinct, it is superior to the mineral in its vitality. In office it constitutes the food and nourishment of the animal, the vesture and ornament of the mineral world, whence alone itself is fed. In other words, plants feed on minerals, animals feed on plants.

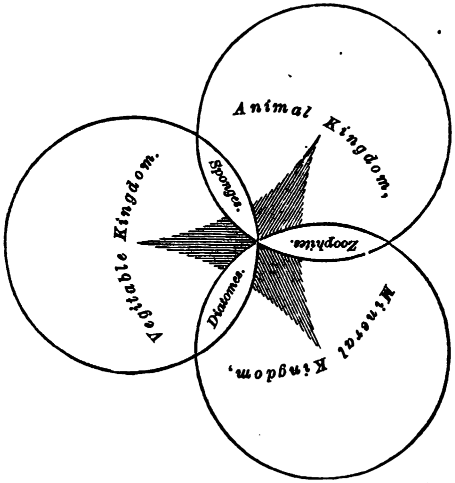


Figure 1. A diagram illustrating these views of the three kingdoms of nature—how related to each other.

36. **Physics** is the general name of the science which treats of the mineral or inorganic world.

37. **Zoology** relates to the animal kingdom.

38. **Botany** is the science of the vegetable kingdom. It includes the knowledge of the forms, organs, structure, growth, and uses of plants, together with their history and classification. Its several departments correspond to the various subjects to which they relate. Thus

39. **Structural botany**, or Organography, treats of the special organs of plants as compared with each other, answering to Comparative Anatomy in the science of Zoology. *Morphology* is a term often used in a similar sense; but it especially relates to the mutual or typical transformations which the organs undergo in the course of development.

40. **Elementary botany** treats of the elementary tissues—the organic elements out of which the vegetable fabric is constructed.

41. **Physiological botany** is that department which relates to the vital action of the several organs and tissues, including both the vital and chemical phenomena in the germination, growth, and reproduction of plants. It has, therefore, a direct and practical bearing upon the labors of husbandry in the propagation and culture of plants, both in the garden and in the field.

42. **Systematic botany** arises from the consideration of plants in relation to each other. It aims to arrange and classify plants into groups and families, according to their mutual affinities and relative rank, so as to constitute of them all one unbroken series or system.

43. **Descriptive botany**, or **phytology**, is the art of expressing the distinctive characters of species and groups of plants with accuracy and precision, in order to their complete recognition. *A flora* is a descriptive work of this kind, embracing the plants of some particular country or district.

44. **Botanical Nomenclature**, which is the art of properly applying names to the species and groups, is intimately associated with the above department. *Terminology* relates to the explanation and application of botanical terms whereby the organs of plants, with their numerous modifications, are accurately designated. This is, therefore, inseparable from Structural Botany.

45. **Ultimate aim of botany.** Finally, in its extended sense, Botany comprehends also the knowledge of the relations of plants to the other departments of nature, particularly to mankind. The ultimate aim of its researches is the development of the boundless resources of the vegetable kingdom for our sustenance and protection as well as education; for the healing of our diseases and the alleviation of our wants and woes. This branch of botanical science is called

46. **Applied botany.** It includes also several departments, as *Medical Botany*, or *Pharmacy*, *Agricultural Botany*, or *Chemistry*, *Pomology*, &c.

47. **Plan of the work.** In the following pages, designed as a complete although compendious treatise for the special convenience of the learner, we shall commence with Structural Botany, whose subjects (the constituent organs of plants) are conspicuous and most readily comprehended.

48. **Secondly**, the cell and the elementary tissues will claim our attention. **Thirdly**, we shall inquire into the vital activities of all these organs, and endeavor to explain the phenomena of vegetable life. **Fourthly**, the principles of vegetable nutrition which constitute the foundation of agricultural science.

49. **In the fifth place** we shall treat of Systematic Botany, the principles of arrangement adopted in the Natural System, and the methods of Botanical Analysis.

50. **Lastly**, the Natural Orders will be defined, and illustrated by our flora, both native and cultivated.

51. NOTWITHSTANDING the extreme brevity of this work, the author believes that no principle of the science essential to a liberal course in Botany is omitted. The brevity is attained by a studied conciseness of expression, and by the omission of all needless illustrations, theoretical views and wordy discussions. In the flora those multitudinous repetitions which are liable to encumber the descriptions of allied groups are avoided, without the sacrifice of minuteness by means of copious tables of analysis.

CHAPTER III.

APPARATUS—METHODS OF STUDY.

52. THE PROPER SEASON FOR THE COMMENCEMENT OF THE STUDY of Botany in schools is in late winter, at the opening of the first session or term after New-Years. The class will thus be prepared before hand by a degree of acquaintance with first principles, for the analysis of the earliest spring flowers—the sweet Epigæa, Anemone, Erigenia or spring beauty, of the North, the yellow jessamine, Chaptalia, or Crysogonum of the South, the blood-root and violet every where.

53. SPECIMENS of leaves, stems, roots, fruit, flowers, &c., in unlimited supply are requisite during the whole course. In the absence of the living, let the dried specimens of the herbarium be consulted. Crayon sketches upon the black-board, if truthful, are always good for displaying minute or obscure forms. In the city, classes in Botany may employ, at small expense, a collector to supply them daily with fresh specimens from the country. Moreover, the gardens and conservatories will furnish to such an abundant supply of *cultivated* species for study and analysis, with almost equal advantage; since the present work embraces, together with the native flora, all exotics which are in any degree common in cultivation.

54. AN HERBARIUM (h. s., *hortus siccus*, dry garden), is a collection of botanic specimens, artificially dried, protected in papers and systematically arranged. *Herbaria are useful in many ways;* (*a.*) for preserving the knowledge of rare, or inaccessible, or lost species; (*b.*) for exchanges, enabling one to possess the flora of other countries; (*c.*) for refreshing one's memory of early scenes and studies; (*d.*) for aiding in more exact researches at leisure; (*e.*) for the comparison of species with species, genus with genus, &c.

55. FOR COLLECTING BOTANIC SPECIMENS, a strong knife for digging and cutting is needed, and a close tin box eighteen inches in length, of a portable form. Enclosed in such a box, with a little moisture, specimens will remain fresh for a week.

56. SPECIMENS FOR THE HERBARIUM should represent the leaves, flowers and fruit, and, if herbaceous, the root also. Much care is requisite in so drying them as to preserve the natural appearance, form and color. The true secret of this art consists in extracting the moisture from them by pressure in an abundance of dry, bibulous paper, before decomposition can take place.

57. THE DRYING PRESS, to be most efficient and convenient, should consist of a dozen quires of ordinary blotting paper, at least 11 x 14 inches, two sheets of wire gauze, (same size) as covers, stiffened by folded edges, and three or four leather straps a yard in length, with buckles. When in use suspend it in the wind and sunshine. In such a press, the specimens dry well in fair weather without once changing. If boards be used for covers instead of wire-gauze, the papers must be changed and dried daily.

58. **Succulent plants** may be immersed in boiling water before pressing, to hasten their desiccation.

59. **The lens**, either single, double, or triple, is almost indispensable in the ordinary pursuits of Morphology or Phytography. In viewing minute flowers or parts of flowers the use of the lens can not be too highly appreciated. For dissection with the lens, a needle inserted in a handle, a penknife and tweezers are required. The dried flowers of the herbarium need to be thrown into boiling water before dissection.

60. **The compound microscope** is undoubtedly a higher aid in scientific investigation than any other instrument of human invention. It is like the bestowment of a new sense, or the opening of a new world. Through this, almost solely, all our knowledge of the cells, the tissues, growth, fertilization, &c., is derived. The skillful use of this noble instrument is itself an art which it is no part of our plan to explain. For such information the student is referred to the works of Carpenter and Quekett.

61. **On the preparation of botanical subjects** for examination we remark briefly. The field of view is necessarily small, and only minute portions of objects can be seen at once. The parts of it are to be brought under inspection successively by the movements of the stage.

62. **The tissues of leaves**, &c., are best seen by transmitted light. They are to be divided by the razor or scalpel into extremely thin parings or cuttings. Such cuttings may be made by holding the leaf between the two halves of a split cork. They are then made wet and viewed upon glass. The stomata are best seen in the epidermis stripped off; but in the sorrel leaf (Oxalis Violacea) they appear beautifully distinct (§ 678, Fig. 585,) upon the entire leaf.

63. **Woody tissues**, &c., may be viewed either as opaque or transparent. Sections and cuttings should be made in all directions, and attached to the glass by water, white of egg, Canada balsam. To obtain the elementary cells separately for inspection, the fragment of wood may be macerated in a few drops of nitric acid added to a grain of chlorate of potassa. Softer structures may be macerated simply in boiling water.

64. **Certain reagents** are applied to the softer and more recent tissues to effect such changes in the cell contents, of either color or form, as shall render them visible. Thus sulphuric acid coagulates the primordial utricle (§ 639); a solution of iodine turns it blue; sugar and nitric acid change it to red.

PART FIRST.

STRUCTURAL BOTANY; OR, ORGANOGRAPHY.

CHAPTER I.

PRIMARY DIVISIONS OF THE VEGETABLE KINGDOM.

65. Two natural Grand Divisions of the Vegetable Kingdom have long been recognized by botanists, viz., the Phænogamia or Flowering Plants; the Cryptogamia, or Flowerless Plants. Besides the obvious distinction made by the presence and absence of the flower,

2, Rose (flowers double)—an Exogen. 3, Lily—an Endogen. 4. Fern—an acrogenous Cryptogam. 5, Lichen—a thallogenous Cryptogam.

66. THESE GRAND DIVISIONS ARE FURTHER DISTINGUISHED by their organic structure and general aspects. In the Phænogamia we find a system of compound organs, such as root, stem, leaf, bud, flower, successively developed on a determinate plan; while in the Cryptogamia, a gradual departure from this plan commences, and they become, at length, in their lowest forms, simple expansions of a uniform tissue, without symmetry or proportion. This distinction is rendered perfectly clear by a reference to

67. EXAMPLES. Compare a *rose* with a *fern*. In the former a regular axis bears buds which are unfolded, some into leaves, others into flowers succeeded by fruit. In the fern no buds nor flowers appear, and the fruit dots sprinkle over the back of the leaf. Again, contrast the *violet* with a *lichen*, where neither stem, root, nor leaf appears, much less flowers, but disc-like expansions with fruit-dust (spores) produced indifferently in any part of them.

68. SUBDIVISIONS OF THE PHÆNOGAMIA. This grand division is itself very naturally resolved into two subdivisions, named by *De Candolle* Exogens and Endogens.

69. EXOGENOUS PLANTS OR EXOGENS (outside-growers), including all the trees (except palms) and most herbaceous plants of temperate regions, are so named, because the additions to the diameter of the stem are made externally to the wood already formed.

70. ENDOGENOUS PLANTS OR ENDOGENS (inside-growers), including the grasses and most bulbous plants of temperate climates, and the palms, canes, etc., south, are so named from the accretions of the stem taking place within the parts already formed.

71. THESE SUBDIVISIONS ARE MORE ACCURATELY DISTINGUISHED by the structure of the seed. The seeds of the Exogens consists of two equal seed-lobes, called cotyledons, as seen in the pea. The seed of the Endogens consists of but one seed-lobe or cotyledon, as in the Indian Corn. On this account Exogens were first called Dicotyledonous (two-cotyledoned) plants, and Endogens, Monocotyledonous (one-cotyledoned) plants;—names quite appropriate, but too hard and long for general use.

72. THEY ARE ALSO VERY READILY DISTINGUISHED by their leaves, which are net-veined in the Exogens, and parallel-veined in the Endogens. Moreover, their flowers are remarkably different, being almost always three-parted in the latter and about five-parted in the former. But all these distinctions, with some others, will be more definitely stated hereafter.

73. THE NAME OF A PLANT or other natural object is twofold,—the trivial or popular name, by which it is generally known in the country; and the Latin name, by which it is accurately designated in science throughout the world. For example, *strawberry* is the popular name, and *Fragaria vesca* the Latin or scientific name of the same plant.

74. In elementary treatises, like the present, for the sake of being readily understood, plants are usually called by their popular names. Yet we earnestly recommend to the learner to accustom himself early to the use of the more accurate names employed in science.

75. THE LATIN NAME IS ALWAYS DOUBLE;—generic and specific. Thus *Fragaria* is generic, or the name of the *genus* of the plant, *vesca* is specific, or the name of the *species*.

76. A SPECIES embraces all such individuals as may have originated from a common stock. Such individuals bear an essential resemblance to each other as well as to their common parent, in all their parts.

77. FOR EXAMPLE, the white clover (Trifolium repens) is a species embracing thousands of cotemporary individuals scattered over our hills and plains, all of common descent, and producing other individuals of their own kind from their seed.

78. VARIETIES. To this law of resemblance in plants of one common origin there are some apparent exceptions. Individuals descended from the same parent often bear flowers differing in color, or fruit differing in flavor, or leaves differing in form, etc. Such plants are called *varieties*. They are never permanent, but exhibit a constant tendency to revert to their original type.

79. EXAMPLES. Varieties occur chiefly in species maintained by cultivation, as the apple, potato, rose, Dahlia. They also occur more or less in native plants (as Hepatica triloba), often rendering the limits of the species extremely doubtful. They are due to the different circumstances of climate, soil, and culture to which they are subjected, and continue distinct only until left again to multiply spontaneously from seed in their own proper soil, or some other change of circumstances.

80. A GENUS is an assemblage of species closely related to each other in the structure of their flowers and fruit, and having more points of resemblance than of difference throughout.

81. ILLUSTRATION. The genus *clover* (Trifolium) includes many species, as the white clover (T. repens), the red clover (T. pratense), the buffalo clover (T. reflexum), etc., agreeing in floral structure and general aspect so obviously that the most hasty observer would notice their relationship. So in the genus *Pinus*, no one would hesitate to include the white pine, the pitch pine, the long-leafed pine (P. strobus, rigida, and palustris), any more than we would fail to observe their differences.

82. Thus individuals are grouped into species, and species are associated into genera. These groups constitute the bases of all the systems of classification in use, whether by artificial or natural methods.

CHAPTER II.

TERM OF PLANT LIFE.

83. PLANT LIFE DEFINED. The vital principle in the plant or its life is known only by its effects. In the animal these effects are, in kind, twofold, indicating two kinds of life, the *organic* and the *nervous* life. In the plant the latter kind is wanting, and the sum of its vital phenomena is popularly expressed in the one word, vegetation.

84. Stages of plant life. The successive phenomena of vegetation are germination, growth, flowering, fruit-bearing, sleeping, dying; and we may add along with these, absorption, digestion, secretion. The development of every plant, herb or tree, commences with the minute embryo, advances through a continual series of transformations, with a gradual increase of stature, to its appointed limit.

85. The life of the plant is a biography. Its form is never permanent, but changing like a series of dissolving views. The picture which it presents to the eye to-day differs, perhaps imperceptibly, from that of yesterday. But let the views be successively sketched when it sprouts from the seed in spring, when clothed in its leafy robes, when crowned with flowers, when laden with ripe fruit, and when dead or dormant in winter—and the pictures differ as widely as those of species the most opposite.

86. The term or period of plant life varies between wide extremes, from the ephemeral mushroom to the church-yard yew, whose years are reckoned by thousands. The term of life for each species is, of course, mainly dependent on its own laws of growth, yet is often modified by the climate and seasons. Thus the castor oil bean (Ricinus) is an annual herb in the Northern States, a shrub in the Southern, and a tree forty feet in height in its native India.

87. Flowering and fruit-bearing is an exhausting process. If it occur within the first or second year of the life of the plant it generally proves the fatal event. In all other cases it is either preceded or followed by a state of needful repose. Now if flowering be prevented by nipping the buds, the tender annual may become perennial, as in the florist's tree-mignionette.

88. We distinguish plants, as to their term of life, into the annual (①), the biennial (②), and the perennial (♃).

89. An annual herb is a plant whose entire life is limited to a single season. It germinates from the seed in spring, attains its growth, blossoms, bears fruit, and dies in autumn, as the flax, corn, morning-glory.

90. A biennial herb is a plant which germinates and vegetates, bearing leaves only the first season, blossoms, bears fruit, and dies the second, as the beet and turnip. Wheat, rye, &c., are annual plants, but when sown in autumn they have the habit of biennials, in consequence of the prevention of flowering by the sudden cold.

91. Monocarpic herbs. The century plant (Agave), the talipot palm, &c., are so called. They vegetate, bearing leaves only, for many years, accumulating materials and strength for one mighty effort in fructification, which being accomplished, they die. But although the vital principle is extinguished in the parent, it survives multiplied a thousand fold in the seed.

92. Perennial plants are such as have an indefinite duration of life, usually of many years. They may be either herbaceous or woody.

93. Herbaceous perennials, or perennial herbs, are plants whose

parts are annual above ground and perennial below. In other words, their roots or subterranean stems live from year to year, sending up annually in spring flowering shoots, which perish after they have ripened their fruit in autumn; as the lily, dandelion, hop.

94. **Woody perennials** usually vegetate several years, and attain well nigh their ordinary stature before flowering; thenceforward they fructify annually, resting or sleeping in winter. They are known as trees, shrubs, bushes and undershrubs—distinctions founded on size alone.

95. A **shrub** is a diminutive tree, limited to eighteen or twenty feet in stature, and generally dividing into branches at or near the surface of the ground (alder, quince). If the woody plant be limited to a still lower growth, say about the human stature, it is called a *bush*, (snow-ball, Andromeda.) If still smaller, it is an *undershrub* (whortleberry).

96. A **tree** is understood to attain to a height many times greater than the human stature, with a permanent woody stem, whose lower part, the trunk, is unbranched.

97. **Longevity of trees.** Some trees live only a few years, rapidly attaining their growth and rapidly decaying, as the peach; others have a longevity exceeding the age of man, and some species outlive many generations.

98. **The age of a tree may be estimated** by the number of wood-circles or rings seen in a cross section of the trunk (§ 667), each ring being (very generally) an annual growth.

99. **Examples.** The known age of an elm, as stated by De Candolle, was 335 years; of a larch, 576; a chestnut, 600; an orange, 630; oaks, from 810 to 1500; yews, 1214 to 2820.

100. **Adanson** estimated the age of the baobabs of Africa at 5000 years. Livingston reduces it to 1800. The yew trees of Britain, as described by Balfour, are of wonderful longevity. One in Bradburn church-yard, Kent, is 3000 years old, and the great yew at Hedsor, Bucks, twenty-seven feet in diameter, has vegetated 3200 years.

101. **Magnitude.** At the first establishment of Dartmouth College, a pine tree was felled upon the college plain which measured 210 feet in height. In the Ohio Valley the red maple attains a girth of 20 feet, the tulip-tree of 30, and the sycamore of more than 60. But the monarch tree of the world is the Sequoya gigantea —the California pine. One which had fallen measured 31 feet in diameter, and 363 feet in length. Among those yet standing are some of still greater dimensions, as beautiful in form as they are sublime in height, the growth (as estimated by the wood-circles) of more than 3000 years.

102. Trees are again distinguished as decidous and evergreen—the former losing their foliage in autumn and remaining naked until the following spring; the latter retaining their leaves and verdure throughout all seasons. The fir tribe (Coniferae) includes nearly all the evergreens of the North; those of the South are far more numerous in kind, *e. g.*, the magnolias, the live-oaks, holly, cherry, palmetto, &c.

CHAPTER III.

THE PHÆNOGAMIA—HOW DEVELOPED.

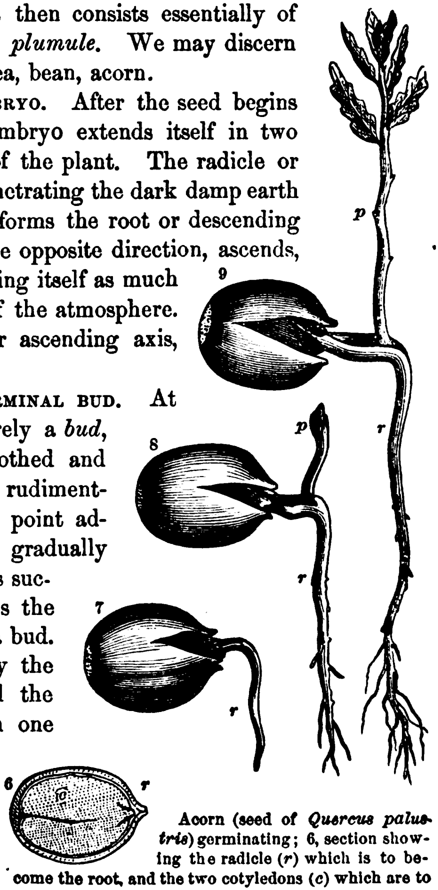
103. **The embryo.** The plant in its earliest stage of life is an *embryo*, contained in a seed. It then consists essentially of two parts, the *radicle* and the *plumule*. We may discern both in many seeds, as the pea, bean, acorn.

104. **Growth of the embryo.** After the seed begins to grow or germinate, the embryo extends itself in two directions, to form the *axis* of the plant. The radicle or root-end grows downward, penetrating the dark damp earth as if to avoid the light, and forms the root or descending axis. The plumule, taking the opposite direction, ascends, seeking the light, and expanding itself as much as possible to the influence of the atmosphere. This constitutes the stem or ascending axis, bearing the leaves.

105. **Growth of the terminal bud.** At first the ascending axis is merely a *bud*, that is, a growing point, clothed and protected by little scales, the rudimentary leaves. As the growing point advances, and its lower scales gradually expand into leaves, new scales successively appear above. Thus the axis is always terminated by a bud.

106. **Axillary buds.** By the growth of the terminal bud the axis is simply lengthened in one direction, an undivided stem. But besides this, buds also exist, ready formed, in the axils of the leaves, one in each.

107. **How branches are formed.** These axillary buds, a part or all of them, may grow and develop like the terminal bud, or they may always sleep, as in the simple-stemmed mullein or palm. But in growing they become *branches*, and these branches



Acorn (seed of *Quercus palustris*) germinating; 6, section showing the radicle (*r*) which is to become the root, and the two cotyledons (*c*) which are to nourish it; 7, the radicle *r*, descending; 8 and 9, the radicle, *r*, descending, and the plumule (*p*) ascending.

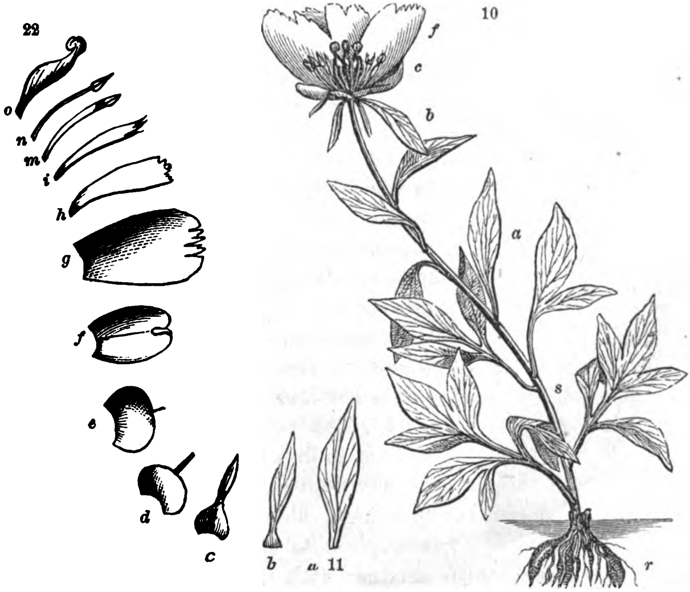
may, in turn, generate buds and *branchlets* in the axils of their own leaves in like manner.

108. BY THE CONTINUAL REPETITION OF THIS SIMPLE PROCESS the vegetable fabric arises, ever advancing in the direction of all its growing points, clothing itself with leaves as it advances, and enlarging the diameter of its axis, until it reaches the limit of existence assigned by its Creator.

109. THE ORGANS OF NUTRITION. Reared by this process alone the plant consists of such organs only as were designed for its own individual nourishment—roots to absorb its food, stem and branches to transmit it, and leaves to digest it. These are called organs of nutrition. But the divine command which caused the tribes of vegetation in their diversified beauty to spring from the earth, required that each plant should have its "seed within itself" for the perpetuation of its kind.

110. HOW THE FLOWER ORIGINATES. In the third stage of vegetation, therefore, a change occurs in the development of some of the buds. The growing point ceases to advance as hitherto, expands its leaves in crowded whorls, each successive whorl undergoing a gradual transformation departing from the original type,—the leaf. Thus, instead of a *leafy branch*, the ordinary progeny of the bud, a *flower* is the result.

111. NATURE OF THE FLOWER. A flower may be considered as a transformed branch, having the leaves crowded together by the non-development of the axis, moulded into more delicate structures, and tinged with more brilliant hues, not only to adorn the face of nature, but to fulfill the important office of reproduction.



10, Pæony, with some of its petals removed to show the stamens and pistils. 11 to 22, the organs, graduated from the leaf to the pistil.

112. **The fruit.** After the flower has fulfilled its office, the deciduous parts fall away, and the remaining energies of the plant are directed to the development of the pistils into the perfect fruit. Let us illustrate this doctrine by tracing out

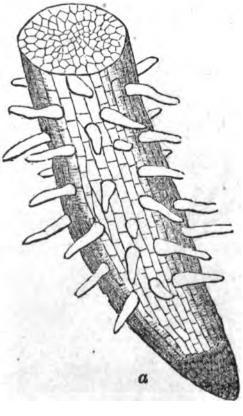
113. **A view of the organs of the pæony,** for example. (*r*) The *root* with its numerous *fibers* and *fabrillæ* (some fibers tuberous) continues the axis downward, and (*s*) the *stem* upward. The *leaves* (*a*) approaching the summit, gradually lose their characteristic divisions, and at length become simple *bracts,* (*b*) still undoubted leaves. Next by an easy gradation they appear as *sepals* (*c, d, e,*) in the calyx, the outer envelope of the flower, with stalk expanded and blade contracted. Then by a somewhat abrupt transition they pass into the delicate and highly colored *petals* of the corolla (*f, g,*), still retaining the essential marks of the leaf. To the corolla next succeed those slender organs called *stamens* (*m, n*), known to be altered leaves from the fact of their being often converted into petals (*i, h*). Lastly the *pistils* (*o,*) destined to bear the seeds, two or more central organs green in color, are each the result of the infolding of a leaf, the mid-vein and united edges being yet discernible.

CHAPTER IV.

THE ROOT OR DESCENDING AXIS.

114. **Definition.** The root is the basis of the plant and the principal organ of nutrition. It originates with the radicle of the seed; the tendency of its growth is downward, and it is generally immersed in the soil.

115. **Diagnosis.** Roots are distinguished from stems by their downward direction, by the presence of absorbing fibers, (fibrillæ), and by the absence of color, pith, buds, leaves, and all other stem-appendages.

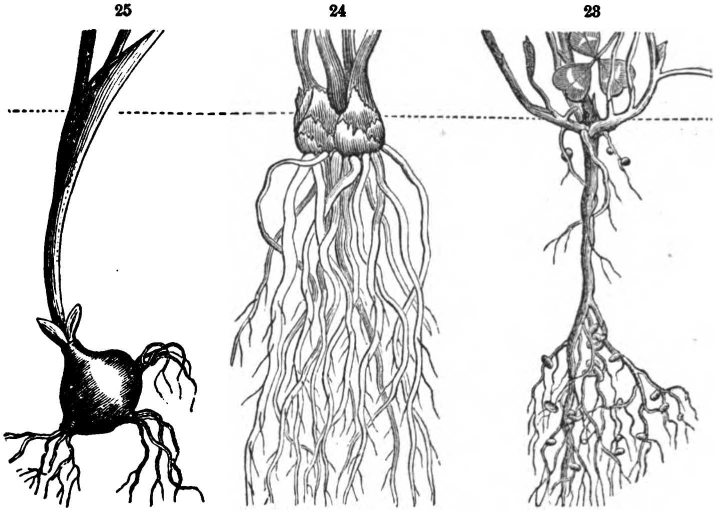


22, *a*. Extremity of a rootlet of maple with its fibrillæ and spongiole (magnified 50 diameters.)

116. **Office.** The two important offices in vegetable life which the root is designed to fulfill, are obvious to every one, viz., to support the plant in its position, and to imbibe from the soil the food and moisture requisite for its growth. How well God has adapted its structure and instincts to this twofold purpose observation is continually showing.

117. **The leading propensity of the root** is, to divide itself into branches, and its only normal appendages are branches, branchlets, fibers and fibrillæ, which are multiplied to an indefinite extent corresponding with the multiplication of the leaves, twigs, &c., above. This at once

insures a firm hold upon the earth, and brings a large absorbing surface in contact with the moist soil.



23. White clover—an axial root (with minute tubers). 24, Buttercups—fibrous roots, inaxial. 25, Erigenia—root tuberous.

118. The summit of the root, or that place where the root meets the stem, is called the *collum*: the remote, opposite extremities, the ends of the fibers, being chiefly active in absorption, are the *spongioles*. Neither of these terms denote distinct organs, but places only, and are often convenient.

119. Fibrillæ, a Latin term, refers to those minute hairs, (seen only with a lens), which clothe the younger fibers. They arise from the tender epidermis or skin, and perish when that thickens into bark. These coöperate with the fibers in the absorption of fluids. These two organs are the only efficient absorbers of liquid nourishment.

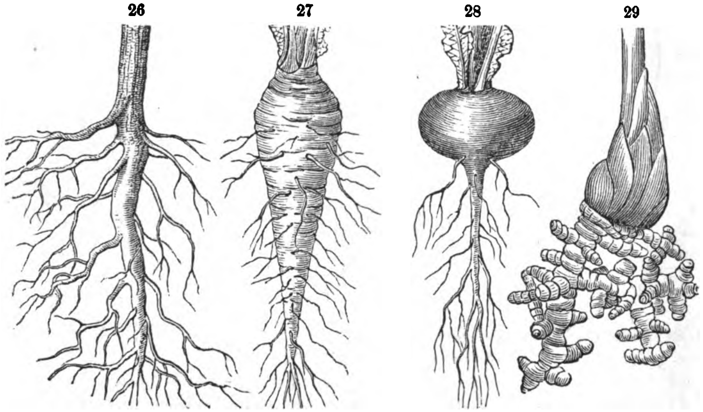
120. Transplanting trees. The fibrillæ are developed and perish annually with the leaves, whose servants they are. Few of them remain after the fall of the leaf. This fact plainly indicates that the proper time for transplanting trees or shrubs is the late autumn, winter, or early spring, when there are but few tender fibrillæ to be injured.

121. Two modes of root-development are definitely distinguished, —the *axial* and the *inaxial*.

122. The axial mode is that where the primary, simple radicle, in growing extends itself downwards in a main body more or less branched, continuous with the stem, and forms the permanent root of the plant.

Such is the case with the mustard, beet, maple, and most of the Dicotyledonous plants. In

123. THE INAXIAL MODE, the primary radicle, proves abortive, never developing into an axial root: but, growing laterally only, it sends out little shoots from its sides, which grow into long, slender roots nearly equal in value, none of them continuous with the stem. Of this nature are the roots of all the grasses, the lilies and the Monocotyledons generally, and of the Cryptogamia. Plants raised from layers, cuttings, tubers, and slips, are necessarily destitute of the axial root.



FIGS. 26, Maple—an axial, ramose root. 27, Parsnip—a fusiform root. 28, Turnip—a napiform root. 29, Corallorhiza—a coralline root.

124. THE VARIOUS FORMS OF THE ROOT are naturally and conveniently referred to these two modes of development. The principal *axial* forms are the ramose, fusiform, napiform, conical. To all these forms the general name, *tap-root*, is applied.

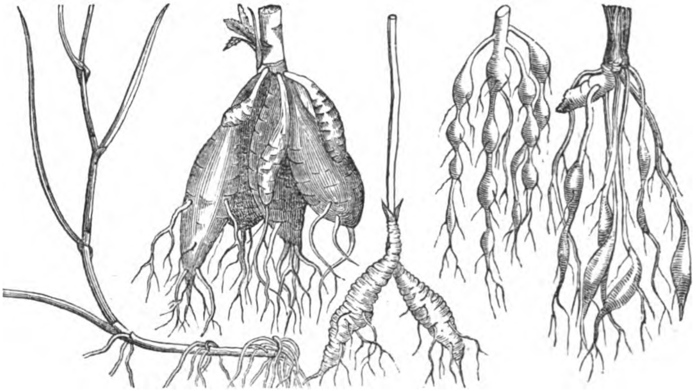
125. THE RAMOSE is the woody tap-root of most trees and shrubs, where the main root branches extensively, and is finally dissolved and lost in multiplied ramifications.

126. TUBEROUS TAP-ROOTS. In herbaceous plants the tap-root often becomes thick and fleshy, with comparatively few branches. This tendency is peculiarly marked in biennials (§ 90), where the root serves as a reservoir of the superabundant food which the plant accumulates during its first year's growth, and keeps in store against the exhausting process of fruit-bearing in its second year. Such is

127. THE FUSIFORM (spindle-shaped) root, thick, succulent, tapering downwards, and also for a short space upwards. The beet, radish, ginseng are examples.

128. THE CONICAL ROOT tapers its whole length, from the collum downwards (carrot).

129. THE NAPIFORM ROOT, (turnip,) swells out in its upper part so that its diameter equals or exceeds its length, as in Erigenia, Panax trifolium (25, 25).



FIGS. 30, Pæony—fibro-tuberous roots. 31, Ginseng—fusiform root. 32, Pelargonium triste—moniliform root. 33, Spirea filipendula—nodulose root. 34, A creeping stem, with adventitious roots.

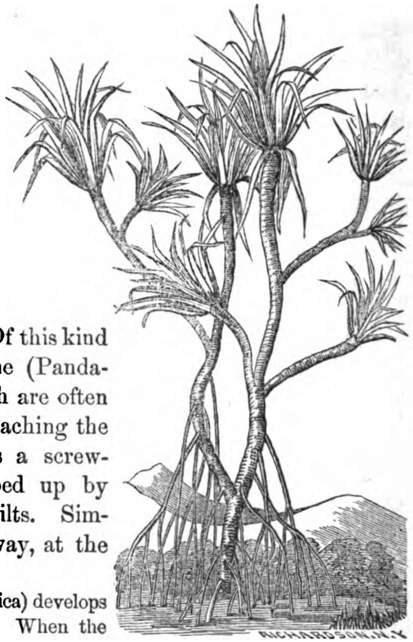
130. THE FORMS OF INAXIAL ROOTS are fibrous, fibro-tuberous, tubercular, coraline, nodulous, moniliform.

131. THE FIBROUS root consists of numerous thread-like divisions sent off directly from the base of the stem, with no main or tap-root. Such are the roots of most grasses, which multiply their fibres excessively in light sandy soils.

132. FIBRO-TUBEROUS ROOTS (or fasciculate). Inaxial roots are so called when some of the fibres are thick and fleshy, as in the asphodel, crow-foot, pæony, Orchis, Dahlia. When the fibre is enlarged in certain parts only, it is NODULOUS, and when the enlargements occur at regular intervals, it is MONILIFORM (necklace-like). When it bears little tubers here and there, as in squirrel-corn (Diclytra Canadensis), it is TUBERCULAR.

133. DEPOSITS OF STARCH, or farinaceous matter, in all these cases, constitute the thickening substance of the root, stored up for the future use of the plant.

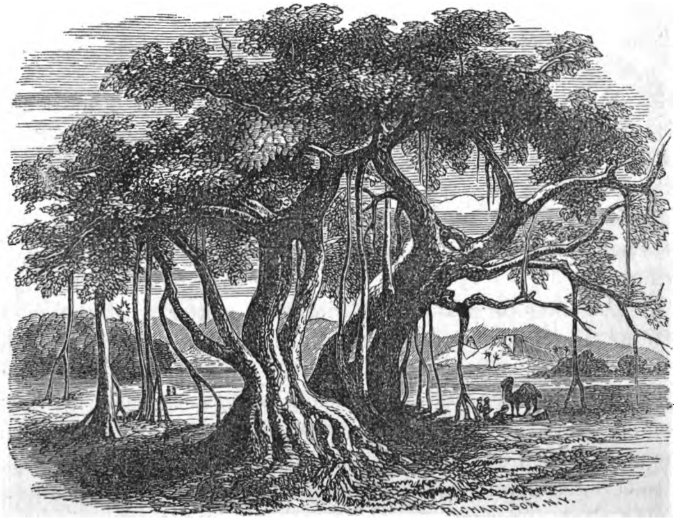
134. ADVENTITIOUS ROOTS are such as originate in some part of the ascending axis,—stem or branches, whether above or below the ground. They are so called because their origin is indeterminate, both in place and time. Examples are seen in the ground-ivy, twin-flower, and other creeping plants. Several special forms should be noticed; as,


85. Screw-pine (Pandanus).

135. The cirrhous roots of certain climbing vines (European ivy, poison ivy, trumpet-creeper) put forth in great numbers from the stem, serving for its mechanical support and no other known use. Again,

136. The fulcra of certain endogenous plants originate high up the stem, and descending obliquely, enter the soil. Of this kind are the roots of the screw-pine (Pandanus) of the conservatories, which are often several feet in length before reaching the ground. The figure represents a screw-pine which was wholly propped up by roots of this kind as if on stilts. Similar roots occur, in a smaller way, at the lower joints of the Indian corn.

137. The Banyan Tree (Ficus Indica) develops adventitious roots on a grand scale. When the branches have stretched out so far as to need additional support, they send forth adventitious roots, descending to the earth. Having penetrated the soil, these roots become supporting columns. The branches


86. Banyan (Ficus Indica).

continuing to advance, send down other roots, which in turn become columns similar to trunks, until a single tree becomes a grove capable of sheltering an army of men.

138. THE MANGROVE (Rhizopora), of the West Indies, sends down axial roots from its branches. The seed germinates before detached, sending down its long radical until it reaches the mud in which these trees grow. Thus the young plants gain a firm standing before quitting their hold of the parent tree.

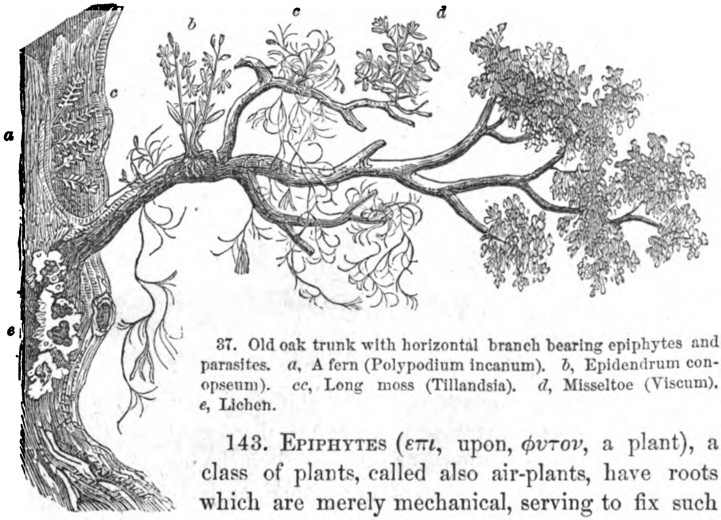
139. TO FAVOR THE DEVELOPMENT OF ADVENTITIOUS ROOTS on any particular part, *keep that part in contact with moist soil.* We often observe such roots to arise naturally, in prostrate branches or stems, at those points which touch the ground. In slips, cuttings, &c., the same thing occurs artificially. Hence to increase the roots of the potato vine, or corn, *heap the earth against the stems.* The madder plant, which is cultivated solely for the rich coloring matter in its roots, is successfully treated in no other way. Its adventitious roots are excessively multiplied by deep spading and high "hilling."

140. TO PRODUCE DWARF TREES it is only necessary, by any contrivance, to retain a quantity of moist earth against the base of the selected branch until it strikes root. Afterwards it may be severed from the tree and transferred to the soil. (Fig. 40, *d*).

141. AXIAL AND INAXIAL ROOTS IN AGRICULTURE. This distinction must never be lost sight of. The former strike deep, anchor firmly, and draw their nourishment from the lower strata of the soil. The latter abide near the surface, and feed upon the upper soil. Hence let us learn

a. Which class of *crops* requires deep and which shallow tillage;
b. Which should succeed each other in the rotation of crops;
c. Which may be sown together in the mixture of crops.

142. TO TRANSFORM A TAP-ROOT TO A FIBROUS. At a certain distance below the collum sever the tap-root without otherwise disturbing the plant. The consequence will be an increased growth of the lateral or fibrous roots nearer the surface of the ground.



37. Old oak trunk with horizontal branch bearing epiphytes and parasites. *a*, A fern (Polypodium incanum). *b*, Epidendrum conopseum). *cc*, Long moss (Tillandsia). *d*, Misseltoe (Viscum). *e*, Lichen.

143. EPIPHYTES (επι, upon, φυτον, a plant), a class of plants, called also air-plants, have roots which are merely mechanical, serving to fix such

plants firmly upon other plants or trees, while they derive their nourishment wholly from the air. The long-moss (Tillandsia) and Conopseum are examples.

144. **Parasites—three classes.** Very different in nature are the roots of those plants called parasites, which feed upon the juices of other plants or trees. Such roots penetrate the bark of the nurse-plant to the cambium layer beneath, and appropriate the stolen juices to their own growth, as the dodder and misseltoe. Other parasites, although standing in the soil, are fixed upon foreign roots, and thence derive either their *entire* sustenance, as the beach-drops and other leafless, colorless plants; or a *part* of their sustenance, as the cow-wheat (Melampyrum), Gerardia.

145. **Subterranean stems.** As there are ærial roots, so there are subterranean stems. These are frequently mistaken for roots, but may be known by their habitually and regularly producing buds. Of this nature are the tubers of the Irish potato, the root-stock of the sweet flag, the bulb of the tulip. But even the true root may sometimes develop buds—accidentally as it were, in consequence of some injury to the upper axis, or some other unnatural condition.

CHAPTER V.

THE STEM, OR ASCENDING AXIS.

146. **Definition.** That part of the plant which originates with the plumule, tends upward in its growth and expands itself to the influence of the air and the light, is called the stem or ascending axis.

147. **The general idea of the axis** is the central substantial portion of the plant, bearing the appendages, viz., the root below and the leaf-organs above. Although not marked by gay coloring or fantastic forms; yet we regard the stem with a lively interest for its substantial value, its gracefulness and lofty proportions, its infinite gradation of form and texture from the tender speedwell crushed beneath the foot to the strong forest oak.

88. Procumbent stem—Chiogenes hispidula.

148. **Direction of its growth.** Although the first direction of the stem's growth is vertical in all plants, there are many in which this direction does not continue, but changes into the oblique or horizontal, either just above the surface of the ground, or just beneath it. If the

stem continues to arise in the original direction, as it most commonly does, it is said to be *erect.* If it grow along the ground without rooting it is said to be *procumbent*, *prostrate*, *trailing.* If it recline upon the ground after having at the base arisen somewhat above it, it is *decumbent.* If it arise obliquely from a prostrate base, it is said to be *ascending*, and if it continue buried beneath the soil, it is *subterranean.*

89. Decumbent stem—Anagallis arvensis.

149. SUBTERRANEAN STEMS may be readily distinguished from the roots by the natural and habitual presence of buds in the former, regularly arranged, while no buds (unless rarely adventitious) exist in the latter.

150. STEMS ARE EITHER SIMPLE OR BRANCHED. The simple stem is produced by the unfolding of the primary bud (the plumule) in the direction of its point alone. As this bud is developed below into the lengthening stem, it is continually reproduced at its summit, and so is always borne at the termination of the stem. Hence the axis is always terminated by a bud.

151. THE BRANCHED STEM, which is by far the most common, is produced by the development of both terminal and axillary buds. The axis produces a bud in the axil of its every leaf, that is at a point just above the origin of the leaf-stalk. These buds remain inactive in the case of the simple stem, as the mullein, but more generally are developed into leafy subdivisions of the axis, and the stem thus becomes branched.

152. A BRANCH is, therefore, a division of the axis produced by the development of an axillary bud. This bud, also, ever renewed, is borne at the termination of the branch, so that axillary buds each in turn become terminal.

153. THE ARRANGEMENT OF THE BRANCHES upon the stem depends therefore upon the arrangement of the leaves, which will be more particularly noticed hereafter. This arrangement is beautifully regular, according to established laws. In this place we briefly notice three general modes:

The *alternate*, where but one branch arises from the node on different sides of the stem, as in the elm.

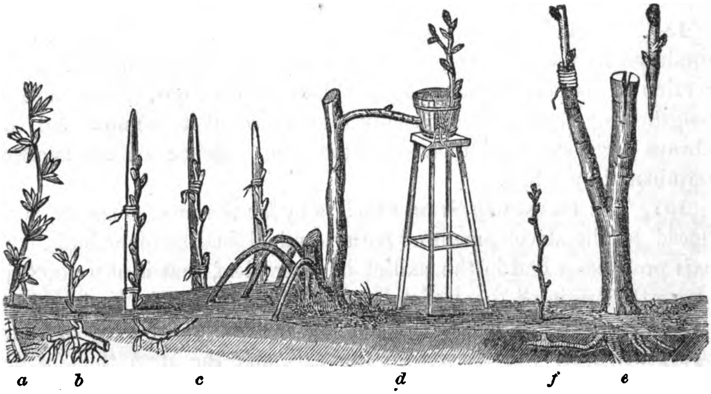
The *opposite*, where two branches stand on opposite sides of the same node, as in the maple.

Verticillate, where three or more branches, equidistant, encircle the stem at each node, as in the pine.

154. THE ANGLE OF DIVERGENCE in branches is also subject to definite rules more obvious in the earlier stages of growth. While the divergence is uniform in the same species, it varies to every degree of the circle in different species, greatly affecting the form of the tree. In general, without marking the exact degree, branches are said to be *erect* (Lombardy poplar), *spreading* or obliquely ascending (common), *divaricate* or at nearly a right angle (oak), *deflexed* (beach), and *pendulous* (weeping willow).

155. CERTAIN KINDS OF BRANCHES are noted for their tendency to produce adventitious roots, and thus to become independent plants. Nurserymen avail themselves of this property in propagation, and name such branches *cions*, *stolons*, *offsets*, *slips*, *layers*, *cuttings*, and *runners*.

156. THE SUCKER is a branch issuing from some underground portion of the plant, leaf-bearing above and sending out roots from its own base, becoming finally a separate, independent plant. The rose and raspberry are thus multiplied.



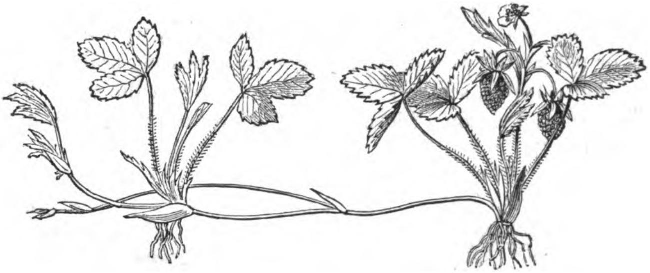
40. *a*, Slip (gooseberry) taking root. *b*, Cutting (grape) taking root. *c*, Stolons or layers artificially arranged for propagation. *d*, A mode of dwarfing (§ 140). *e*, Cions—process of grafting. *f*, A Sucker.

157. THE STOLON or LAYER is a branch issuing from some above-ground portion of the stem, and afterward declining to the ground takes root at or near its extremity, sends up new shoots, and becomes a new plant. The hobble-bush and black raspberry do this naturally, and gardeners imitate the process in many plants.

158. THE CION is any healthy twig or branchlet bearing one or more buds, used by the gardeners in the common process of grafting. *Slips* and *cuttings* are fragments of ordinary branches or stems con-

sisting of young wood bearing one or more buds. These "strike" root when planted in the earth. So the grape-vine and hop.

159. THE OFFSET is a term applied to short side-branches ending in a tuft (rosette) of leaves, and capable of taking root when separated from the parent plant, as in houseleek.



41, A strawberry plant (Fragaria vesca) sending out a runner.

160. THE RUNNER is a prostrate, filiform branch issuing from certain short-stemmed herbs, extending itself along the surface of the ground, striking root at its end without being buried. Thence leaves arise and a new plant, which in turn sends out new runners; as in the strawberry.

161. THE NODE or joint of the stem marks a definite point of a peculiar organization where the leaf with its axillary bud arises. The nodes occur at regular intervals, and the spaces between them are termed *internodes.* This provides for the symmetrical arrangement of the leaves and branches of the stem. In the root no such provision is made, and the branches have no manner of arrangement.

162. WHY THE STEM GRADUALLY DIMINISHES UPWARDS. In the internodes the fibres composing the stem are parallel, but at the nodes this order is interrupted in consequence of some of the inner fibres from below turning outwards into the leafstalk, causing more or less a jointed appearance. Hence each internode contains fewer fibres than those below it.

163. HOW THE STEM GROWS. The growth of the stem consists in the development of the internodes. In the bud the nodes are closely crowded together, with no perceptible internodes, thus bringing the rudimentary leaves in close contact with each other. But in the stem, which is afterwards evolved from that bud, we see full grown leaves separated by considerable spaces. That is, while leaves are developed from the rudiments, internodes are evolved from the growing point.

164. BUT THERE ARE EXCEPTIONS here as to all other rules in science, adding another element of diversity to the endless gradation of form in Nature's works. In

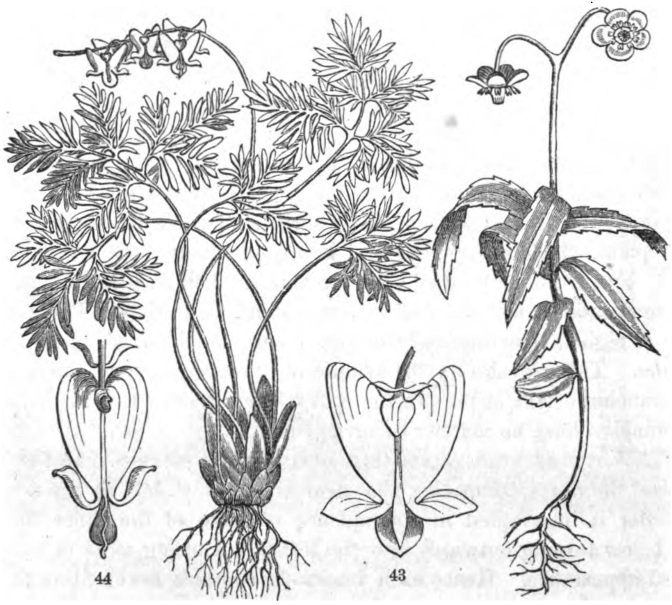
many plants the axis of the primary bud does not develop into internodes at all, or but partially in various degrees, as in the Trillium, Crocus, blood-root. Such stems seldom appear above ground, and are said to be *subterranean.*

165. This fact makes a wide difference in the forms of stems, and naturally constitutes them into *two great divisions*, viz., the leaf-stem and the scale-stem.

166. THE LEAF-STEMS are those forms which, with internodes fully developed, arise into the air crowned with leaves. The principal forms are the caulis, culm, trunk, caudex, vine.

167. THE SCALE-STEMS are those forms which, with internodes partially or not at all developed, and generally bearing scales, which are undeveloped leaves, scarcely emerge from beneath the soil. They are the creeper and rhizoma (developed), the crown, tuber, corn and bulb (undeveloped).

42. 45.



42. Scale-stem, (Dicentra cucullaria). 43, A flower of the same. 44, A flower of D. Canadensis. 45, Leaf-stem (Chimaphila maculata).

168. THE LEAF-STEMS ARE EITHER HERBACEOUS OR WOODY. The herbaceous, whether arising from annual, biennial or perennial roots, bear fruit but one season and then perish at least down to the root, scarcely becoming woody; as the ① mustard, ② radish, and the ♃ grasses. The woody leaf-stems survive the winter, and become firm and solid in texture in after years.

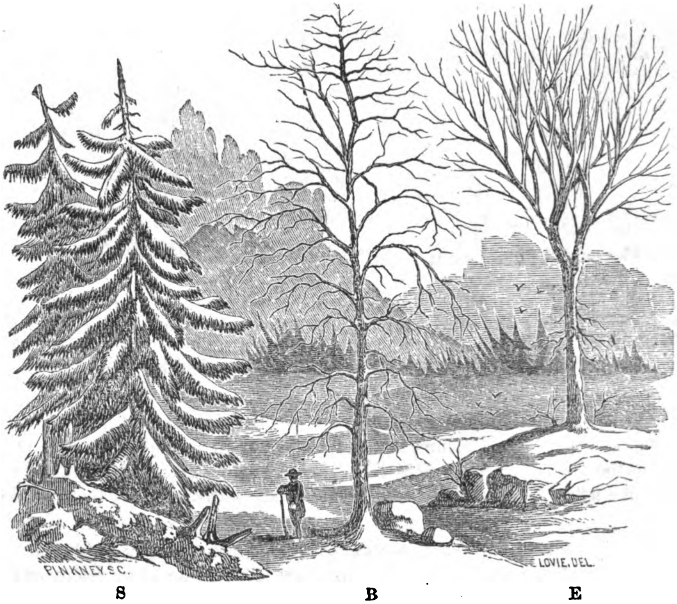
169. CAULIS is a term generally applied to the annual leaf-stems of

herbaceous plants. "Halm" is a term used in England with the same signification. *Caulescent* and *accaulescent* are convenient terms denoting, the former the presence, and the latter the absence of the caulis or aerial stem.

170. The Culm is the stem of the grasses and the sedges, generally jointed, often hollow, rarely becoming woody, as in cane and bamboo.

171. The trunk is the name of the peculiar stems of arborescent plants. It is the central column or axis which supports their branching tops and withstands the assaults of the wind by means of the great firmness and strength of the woody or ligneous tissue with which it abounds.

172. Various forms. The trunk is usually seen simple and columnar below, for a certain space, then variously dividing itself into branches. Here it is cylindrical, straight and erect, as in the forest pine; prismatic often, as in the gum-tree; gnarled and curved, as in the oak; or inclined far over its base, as in the sycamore.



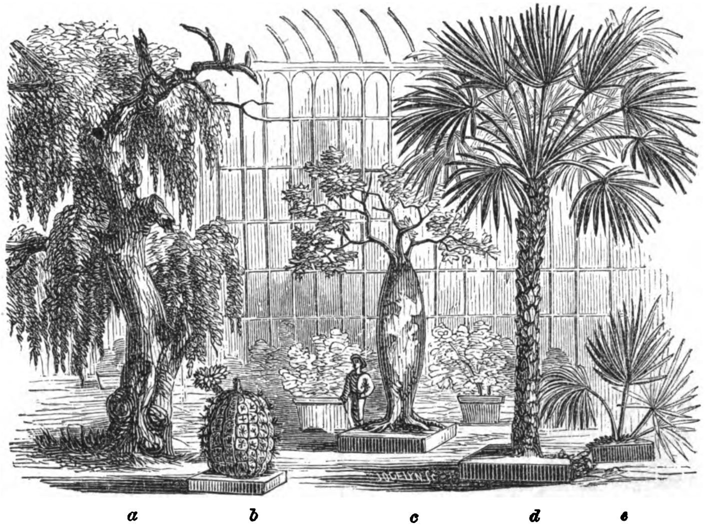
46. S, Spruce. B, Beech. E, Elm; to illustrate excurrent and solvent axis,

173. In dividing itself into branches we observe two general modes, with their numerous variations, strikingly characterizing the true forms. In the one, named by Lindley the excurrent, the trunk, from the superior vigor of its terminal bud, takes precedence of the branches, and runs through to the summit, as in the

beech, birch, oak, and especially in the spruce—trees with oval or pyramidal crowns.

174. But in the other, the solvent axis, as seen in the elm, the apple-tree, the trunk suddenly divides into several subequal branches, which thence depart with different degrees of divergency, giving the urn form to the elm, the rounded form to the apple-tree, the depressed form to the sloe-tree (Viburnum) and dogwood.

175. The form of the trunk sometimes changes with age, especially in tropical regions, some distorted by huge local excrescences, others swelling out in the midst to "aldermanic" proportions.



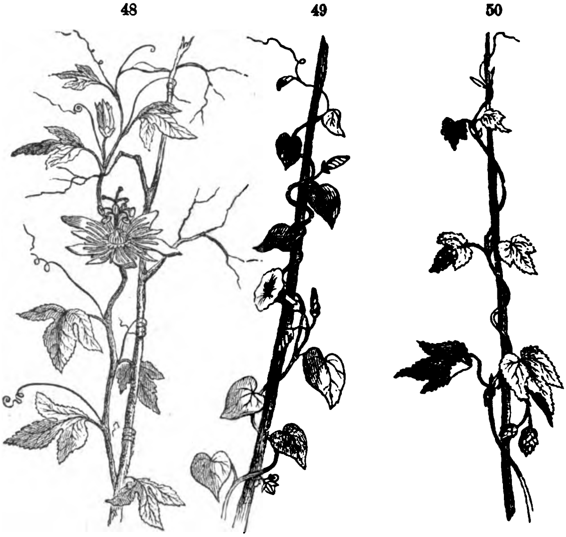
47. *a*, An old willow (Salix Babylonica) with gnarled and misshapen *trunk*. *b*, *Caudex* of a cactus (Echinocactus Ottonis). *c*, Bombax, of Brazilian forests, with distended trunk. *d*, Palmetto (Chamærops), the caudex rough with the persistent bases of the petioles.

176. Caudex is a term now applied to the peculiar trunk of the palms and tree-ferns, simple, branchless columns, or rarely dividing in advanced age. It is produced by the growth of the terminal bud alone, and its sides are marked by the scars of the fallen leaf-stalks of former years, or are yet covered by their persistent bases.

177. The stock or caudex of the cactus tribe is extraordinary in form and substance. It is often jointed, prismatic, branched, always greenish, fleshy, and full of a watery juice. Instead of leaves, its lateral buds develop spines only, the stem itself performing the functions of leaves. These plants abound in the warm regions of tropical America, and afford a cooling, acid beverage to the thirsty traveler when springs dry up under the torrid sun.

178. The vine is either herbaceous or woody. It is a stem too slender and weak to stand *erect*, but trails along the ground or any convenient support. Sometimes, by means of special organs for this purpose,

called *tendrils*, it ascends trees and other objects to a great height, as the grape, gourd, and other *climbing vines*.



Vines. 48, Passion-flower (Passiflora lutea) climbing by tendrils. 49, Morning-glory, twining from left to right. 50, Hop, twining from right to left.

179. THE TWINING VINE, having also a length greatly disproportioned to its diameter, supports itself on other plants or objects by entwining *itself* around them, being destitute of tendrils. Thus the hop ascends into the air by foreign aid, and it is a curious fact that the direction of its winding is always the same, viz., with the sun, from left to right; nor can any artificial training induce it to reverse its course. This is a general law among twining stems. Every individual plant of the same species revolves in the same direction, although opposite directions may characterize different species. Thus the morning glory revolves always against the sun.

180. THE FORMS OF SCALE-STEMS are singular, often distorted in consequence of their underground growth and the unequal development of the internodes. They commonly belong to perennial herbs, and the principal forms are described as follows; but intermediate connecting forms are very numerous and often perplexing.

181. THE CREEPER is either subaerial or subterranean. In the former case it is prostrate, running and rooting at every joint, and hardly distinguishable otherwise from leaf-stems, as the twin-flower (Linnæa), the partridge-berry (Mitchella). In the latter case it is more commonly clothed with scales, often branching extensively, rooting at the nodes, exceedingly tenacious of life, extending horizontally in all directions beneath the soil, annually sending up from its terminal buds erect stems

into the air. The witch-grass (Triticum repens) is an example. Such plants are a sore evil to the garden. They can have no better cultivation than to be torn and cut to pieces by the spade of the angry gardener, since they are thus multiplied as many times as there are fragments.

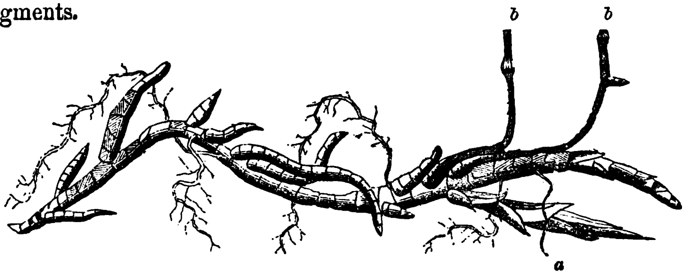


Fig. 51. Creeper of "Nimble Will," or witch-grass; *a*, Bud; *bb*, Bases of culms.

182. Utility. Repent stems of this kind are not, however, without their use. They frequently abound in loose, sandy soil, which they serve to bind and secure against the inroads of the water and even the sea itself. Holland is said to owe its very existence to the repent stems of such plants as the mat-grass (Arundo arenaria), Carex arenarius and Elymus arenarius, which overrun the artificial dykes upon its shores, and by their innumerable roots and creepers apparently bind the loose sand into a firm barrier against the washing of the waves. So the *turf*, chiefly composed of repent grass-stems, forms the only security of our own sandy or clayey hills against the washing rains.

183. The rhizome or root-stock differs from the creeper only in being shorter and thicker, having its internodes but partially developed. It is a prostrate, fleshy, rooting stem, either wholly or partially subterranean, often scaly with the bases of undeveloped leaves, or marked with the scars of former leaves, and yearly producing new shoots and roots. Such is the fleshy, horizontal portion of the blood-root, sweet-flag, water-lily, bramble (the latter hardly different from the creeper).

184. The growth of the rhizome is instructive, marking its peculiar character. Each joint marks the growth of a year. In spring the terminal bud unfolds into

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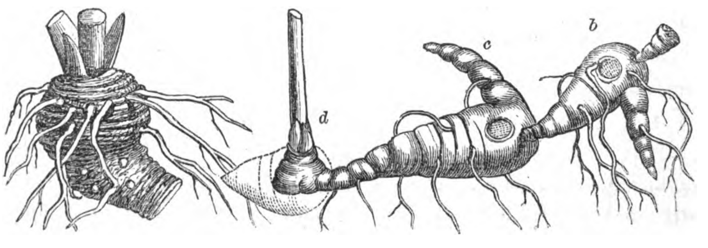


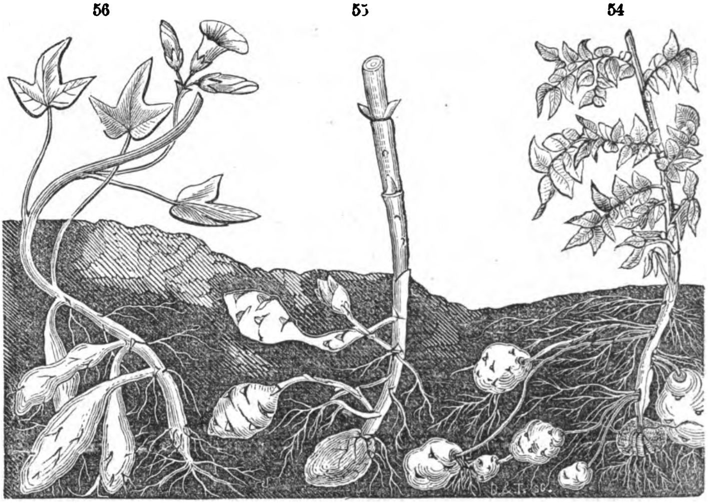
Fig. 52. Rhizoma of Solomon's-seal (Polygonatum multiflora) *a*, Fragment of the first year's growth; *b*, the second year's growth; *c*, growth of the third year; *d*, growth of the present (fourth) year, bearing the stem which, on decaying, will leave a scar (seal) like the rest. 53. Premorse stem of Trillium.

leaves and flowers to perish in autumn—a new bud to open the following spring—and a new internode with its roots to abide several years. The number of joints indicates, not the age of the plant, but the destined age of each internode. Thus if there are three joints, we infer that they are triennial, perishing after the third season, while the plant still grows on.

185. The premorse root-stock, formerly described as a root, is a short, erect rhizome, ending abruptly below as if bitten square off (præmorsus). This is owing to the death of the earlier and lower internodes in succession, as in the horizontal rhizome. Scabious, Viola pedata, benjamin-root (Trillium) are examples.

186. Crown of the root designates a short stem with condensed internodes, remaining upon some perennial roots, at or beneath the surface soil after the leaves and annual stems have perished.

187. The tuber is an annual thickened portion of a subterranean stem or branch, provided with latent buds called eyes, from which new plants ensue the succeeding year. It is the fact of its origin with the ascending axis, and the production of buds that places the tuber among stems instead of roots. The potato and artichoke are examples.

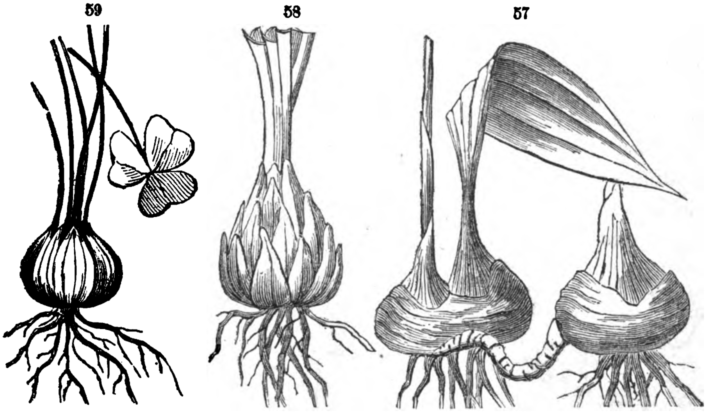


Tubers as they grow. 54, The common potato (Salanum). 55, Artichoke (Helianthus) 56, Sweet potato (Convolvulus).

188. How the potato grows. The stem of the potato-plant sends out roots from its base, and branches above like other plants; but we observe that its branches have two distinct modes of development. Those branches which arise into the air, whether issuing from the above-ground or the under-ground portion of the stem, expand regularly into leaves, &c., while those lower branches which continue to grope in the dark, damp ground, cease at length to elongate, swell up at the ends into tubers with developed buds and abundance of nutritious matter in reserve for renewed growth the following year.

189. **The corm** is an under-ground, solid, fleshy stem, with condensed internodes, never extending, but remaining of a rounded form covered with thin scales. It is distinguished from roots by its leaf-bud, which is either borne at the summit, as in the crocus, or at the side, as in the colchicum and putty-root (Aplectrum).

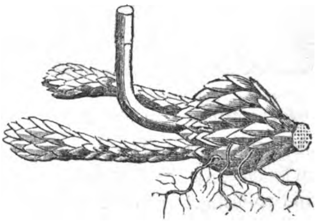
190. **How the corm grows.** The corm usuully accomplishes its part in vegetation in one or two seasons, and then gradually yields up its substance and life for the nourishment of the new progeny formed from the axils of its upper scales in case of the Crocus and Gladiolus, or the single new corm from the axil of a lateral scale, as in Colchicum.



57, Corms of putty-root (Aplectrum); *a*, of last year, *b*, of the present year. 58, Scale bulb of white lily. 59, Scale bulb of Oxalis violacea.

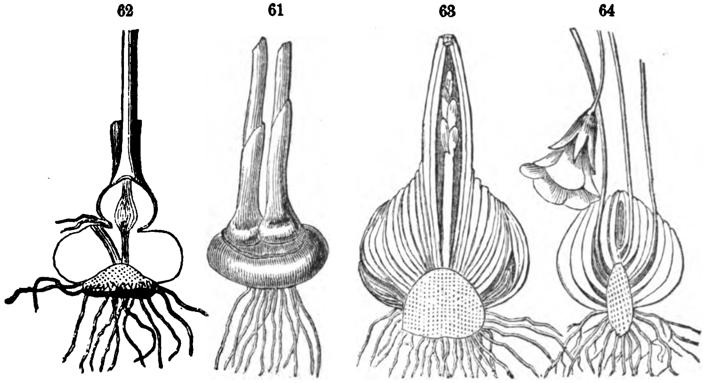
191. **The Bulb** partakes largely of the nature of the bud. It consists of a short, dilated axis, bearing an oval mass of thick, fleshy scales closely packed above, a circle of adventitious roots around its base, and a flowering stem from the terminal, or a lateral bud.

192. **How multiplied.** Bulbs are renewed or multiplied annually at the approach of winter by the development of bulbs from the axils of the scales, which increase at the expense of the old, and ultimately become detached. Bulbs which flower from the terminal bud are necessarily either annual or biennial: those flowering from an axillary bud may be perennial, as the terminal bud may in this case continue to develop new scales indefinitely.



60. Bulb of Lilium superbum, with habit of a rhizome; *a*, full-grown bulb sending up a terminal stem *c*, and two offsets *bb*, for the bulbs of next year.

193. **Bulbs** are said to be *tunicated* when they consist of concentric layers, each entire and enclosing all within it, as in the onion. But the more common variety is the *scaly bulb*—consisting of fleshy, concave scales arranged spirally upon the axis, as in the lily.



61, Corm of Crocus, with new ones forming above; 62, Vertical section of the same; 63, Section of bulb of Hyacinth with terminal scape and axillary bulblet; 64, Section of bulb of Oxalis violacea, with axillary scapes.

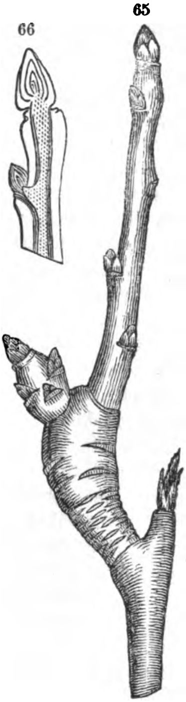
194. THE TUBER, CORM AND BULB ARE ANALOGOUS FORMS approaching by degrees to the character of the bud, which consists of a little axis bearing a covering of scales. In the tuber the axis is excessively developed while the scales are reduced to mere linear points. In the corm the analogy is far more evident, for the axis is less excessive and the scales more manifest, and lastly in the bulb the analogy is complete, or overdone, the scales often becoming excessive.

CHAPTER VI.

THE LEAF-BUD.

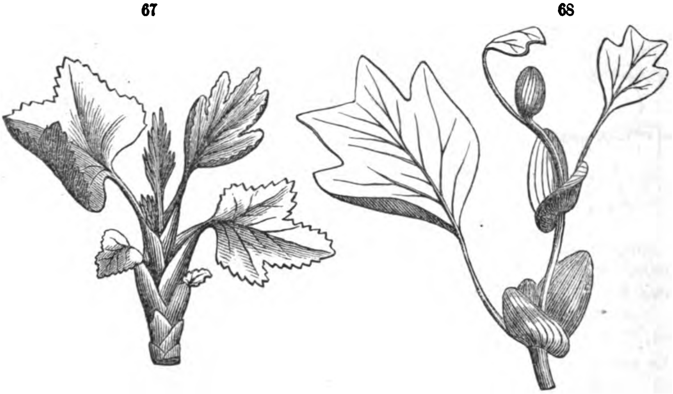
195. It is but a step from the study of the bulb to that of the leaf-bud. Buds are of two kinds in respect to their contents; the *leaf-bud* containing the rudiments of a leafy stem or branch, the *flower-bud* containing the same elements transformed into the nascent organs of a flower for the purpose of reproduction.

196. THE LEAF-BUD consists of a brief, cone-shaped axis with a tender growing point, bearing a protecting covering of imbricated scales and incipient leaves.



65. Branch of pear tree. The terminal bud *a*, having been destroyed, an axillary bud supplied its place, and formed the axis *b*. *c*, Thickened branch with flower-buds, *d*, branch with leaf-buds. 66. *t*, section of terminal bud; *l*, of axillary bud.

197. **Nature of the scales.** The scaly envelops of the bud appear to be either the rudimentary leaves or stipules of the preceding year, formed late in the season, arrested in their development by the frosts and scanty nourishment, and reduced to a sear and hardened state. If the bud of the rose, tulip-tree, or horse-chestnut be examined when swollen in the spring, the student will notice a gradual transition from the outer *scales* to the evident *leaves* or *stipules* within.



67, Bud of currant unfolding,—the scales gradually becoming leaves. 68, Bud of tulip-tree,—the scales unfolding into stipules.

198. It is an interesting **illustration of designing Wisdom** that buds are furnished with scales only in wintry climates. In the Torrid Zone, or in conservatories, where the temperature is equalized through the year, plants develop their foliage into buds immediately after formation, without clothing them in scales. In annual plants also, the buds are destitute of scales, not being destined to survive the winter. Hence it is evident that the transformation of autumnal leaves into scales, is a means ordained by the great Author of Nature to protect the young shoots in their incipient stages from sudden cold and moisture,—an office which they effectually fulfil by their numerous downy folds and their insoluble coat of resin.

199. **How buds are protected.** In many trees the bud-scales are clothed with dense, downy hairs. In others, as in the horse-chestnut, balm of Gilead, and other species of poplar, the buds are covered with a viscid, aromatic resin, resembling a coat of varnish. A considerable quantity may be separated from a handful of such buds in boiling water.

200. **The parent bud.** In regard to position, buds are either terminal or axillary—a distinction already noticed. The plumule of the embryo is the original parent bud, containing within its minute organization the manifold parts of the future plant—stem, leaves, flower, fruit—all to be successively unfolded in future months or years. The unfolding of this first *terminal* bud in the one direction of its point produces the simple stem.

201. **Origin of branches.** But in every plant a special provision is made for the development of branches. It is a general law that every expanding leaf shall subtend an infant bud in its axil, that is, in the upper angle of the insertion of the leaf-stalk; hence the plant may always have as many axillary buds as it has leaves.

202. **Axillary buds** are especially noted as being either **active** or

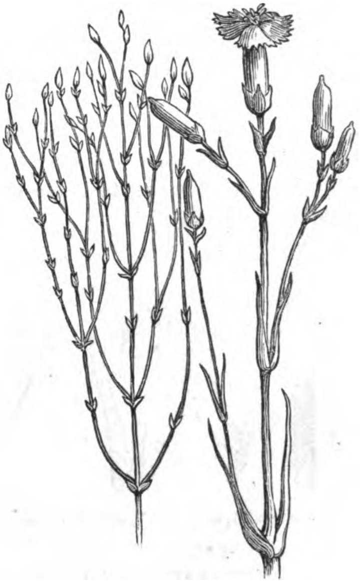
LATENT. In the former case they are unfolded into branches at once, or in the spring following their formation. But *latent* buds suspend their activities from year to year, or perhaps are never quickened into growth.

203. AXILLARY BUDS BECOME TERMINAL so soon as their development fairly commences, therefore each branch also has a terminal bud, and, like the main axis, is capable of extending its growth as long as that bud remains unharmed. If it be destroyed by violence or frost, or should it be transformed into a flower-bud, the growth in that direction forever ceases.

204. THE SUPPRESSION OF AXILLARY BUDS tends, of course, to simplify the form of the plant. Their total suppression during the first year's growth of the terminal bud is common, as in the annual stem of mullein and in most perennial stems. When axillary buds remain permanently latent, and only the terminal bud unfolds year after year, a simple, branchless trunk, crowned with a solitary tuft of leaves, is the result, as in the palmetto of our southern borders.

205. A PARTIAL SUPPRESSION OF BUDS occurs in almost all species, and generally in some definite order. In plants with opposite leaves, sometimes one bud of the pair at each node is developed and the other is suppressed, as in the pink tribe (Caryophyllaceæ). When both buds are developed, the branches, appearing in pairs like arms, are said to be *brachiate*, as in the Labiatæ. In many trees the terminal buds are arrested by inflorescence each season, and the growth is continued by axillary buds alone, as in the Catalpa and horse-chestnut. In all trees, indeed, buds are suppressed more or less, from various causes, disguising at length the intended symmetry of the branches, to the utter confusion of twigs and spray.

206. ACCESSORY BUDS, one or more, are sometimes found just above the true axillary bud, or clustered with it, and only distinguished from it by their smaller size: as in the cherry and honeysuckle.



69, Hypericum Sarothra, with brachiate branches. **70**, Pink (Dianthus)—axillary buds alternately suppressed.

207. ADVENTITIOUS OR ACCIDENTAL BUDS are such as are neither terminal nor axillary. They occasionally appear on any part of the

plant in the internodes of the stem or branches, on the root, or even leaves.

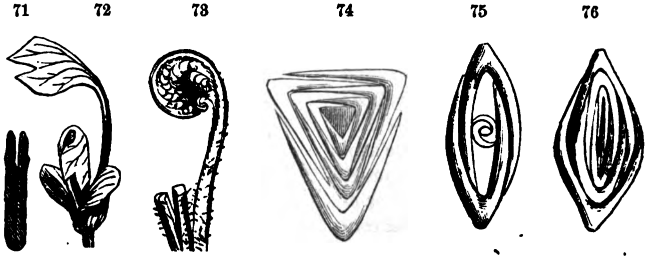
208. Causes and examples. Such buds generally result from some abnormal condition of the plant, from pruning or other destruction of branches or stem above, while the roots remain in full vigor; thus destroying the equilibrium of vital force between the upper and lower axis. The leaf of the walking-fern emits rootlets and buds at its apex; the leaf of Bryophyllum from its margin, each bud here also preceded by a rootlet. Some plants are thus artificially propagated in conservatories from the influence of heat and moisture on a leaf or the fragment of a leaf.

209. Vernation or præfoliation are terms denoting the mode of arrangement and folding of the leaf-organs composing the bud. This arrangement is definitely varied in different orders of plants, furnishing useful distinctions in systematic botany.

210. The vernation of the bud is exhibited in an interesting manner by making with a keen instrument a cross-section of it in its swollen state, just before expansion; or it may be well observed by removing one by one the scales.

211. The forms of vernation are entirely analogous to those of æstivation, and denoted by similar terms. We shall here notice only such as are more peculiar to the leaf-buds.

212. Vernation is considered in *two different aspects*, first, the manner in which the leaf itself is folded; second, the arrangement of the leaves in respect to each other. This depends much upon the phyllotaxy. (§ 220.)



Vernation, 71, of oak leaf; 72, of Liriodendron (tulip tree); 73, of fern; 74, of carex; 75, sage; 76, iris.

213. Each leaf alone considered is either *flat* and *open*, as in the mistletoe, or it is *folded* or *rolled*, as follows:

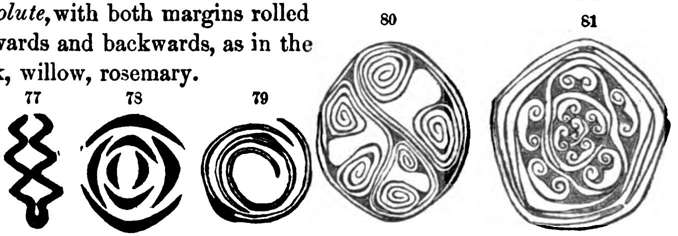
Reclined, when folded crosswise with apex bent over forward towards the base as in the tulip-tree.

Conduplicate, when folded perpendicularly, with the lateral halves brought together, face to face, as in the oak.

Plaited or plicate, each leaf folded like a fan; vine, birch.

Circinate, when each leaf is rolled or coiled downwards from the apex, as in the sun-dew and ferns.

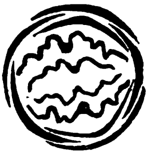
Convolute, the leaf wholly rolled up from one of its sides, as in the cherry. *Involute*, having both edges rolled inwards as in apple, violet *Revolute*, with both margins rolled outwards and backwards, as in the dock, willow, rosemary.



Vernation. 77, of birch leaf; 78, of lilac, (imbricate); 79, cherry leaves, (convolute); 80, dock bud, (revolute); 81, balm of Gilead, (involute).

214. **The general vernation** is loosely distinguished in descriptive botany as valvate (edges meeting), and imbricate (edges overlapping), terms to be noticed hereafter. The valvate more often occurs in plants with opposite leaves. Imbricated vernation is

Equitant (riding astraddle), when conduplicate leaves alternately embrace—the outer one the next inner, by its unfolded margins, as in the privet and iris.



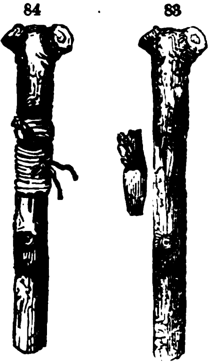
82. Vernation of Sycamore bud.

Obvolute, or half-equitant, when the outer leaf embraces only one of the margins of the inner, as in the sage.

Triquetrous, where the bud is triangular in section, and the leaves equitant at each angle, as in the Carices.

215. **The principle of budding.** Each leaf-bud may be regarded as a distinct individual, capable of vegetating either in its native position, or when removed to another, as is extensively practiced in the important operation of *budding*.

216. **Bulblets.** In the tiger-lily, Cicuta bulbifera, and Aspidium bulbiferum, the axillary buds spontaneously detach themselves, fall to the ground, and become new plants. These remarkable little bodies are called *bulblets*.



83, 84, Showing the process of "budding."

CHAPTER VII.

THE LEAF.

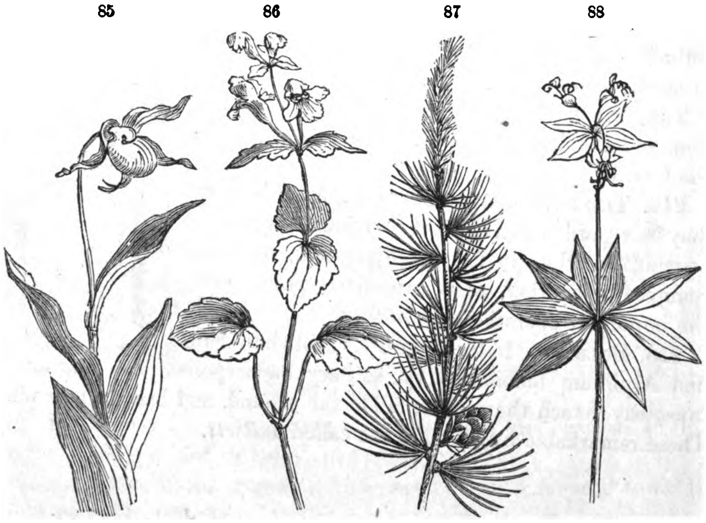
217. **Its importance.** The leaf constitutes the verdure of plants, and is by far the most conspicuous and beautiful object in the scenery of nature. It is also of the highest importance in the vegetable economy, being the organ of *digestion* and *respiration.*

218. **The leaf is characterized** by a thin and expanded form, presenting the largest possible surface to the action of the air and light, which agents are indispensable to the life and increase of the plant.

219. **The color of the leaf** is almost universally green, which of all colors is the most agreeable to the eye; but its intensity varies by infinite shades, and is often finely contrasted with the more delicate tints of the flower. Towards maturity its verdure is changed, often to the most brilliant hues, as red, crimson, orange, yellow, giving our autumnal forest scenery a gaiety, variety, and splendor of coloring which the wildest fancy could scarcely surpass.

PHYLLOTAXY, OR LEAF-ARRANGEMENT.

220. As the position of the leaf upon the stem marks the position of the axillary bud, it follows that the order of the leaf-arrangement will be the order of the branches also. The careful investigation of this subject has developed a science of unexpected exactness and beauty, called phyllotaxy (*φύλλον*, a leaf, *τάξις*, order.)



85, Ladies'-slipper (leaves alternate); 86. Synandra grandiflora (leaves opposite); 88, Medeola Virginica (leaves verticillate); 87, Larix Americana (leaves fasciculate).

221. Position upon the stem. Leaves are *radical* when they grow out of the stem at or beneath the surface of the ground, so as to appear to grow from the roots; *cauline* when they grow from the stem, and *ramial* (*ramus*, a branch), when from the branches.

222. Insertion upon the axis. The arrangement of the scales and young leaves in the bud appears to be in close, contiguous circles. By the development of the axis the leaves are separated, and their order variously modified, according to the following general modes:—

Alternate, one above another on opposite sides, as in the elm.

Scattered, irregularly spiral, as in the potato vine.

Rosulate, clustered regularly, like the petals of a rose, as in the plantain and shepherd's-purse.

Fasciculate, tufted, clustered many together in the axil, as seen in the pine, larch, berberry.

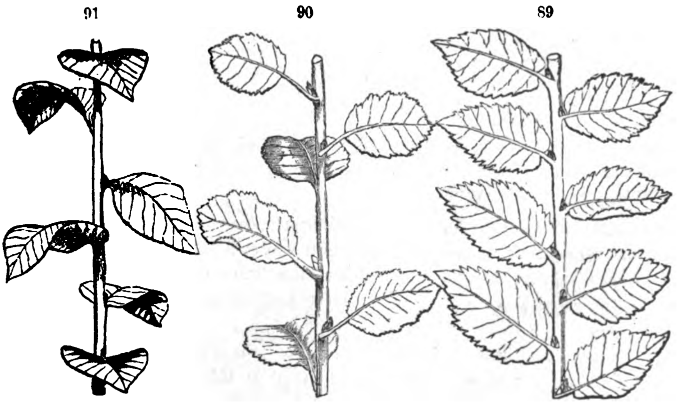
Opposite, two, against each other, at the same node. Ex. maple.

Verticillate, or whorled, more than two in a circle at each node, as in the meadow-lily, trumpet-weed. We may reduce all these modes to

223. Two general types,—the *alternate*, including all cases with one leaf at each node,—the *opposite*, including cases with two or more leaves at each node.

224. The true character of the alternate type may be learned by an experiment. Take a straight leafy shoot or stem of the elm or flax, or any other plant with seemingly scattered leaves, and beginning with the lowest leaf, pass a thread to the next above, thence to the next in the same direction, and so on by all the leaves to the top; the thread will form a regular *spiral*.

225. Fasciculate leaves are the members of an undeveloped branch, and in



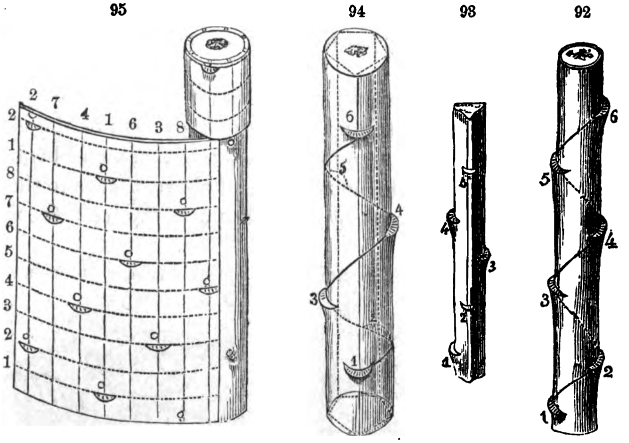
Phyllotaxy. 89, leafy branch of elm,—cycle $\frac{1}{2}$. 90, leafy branch of alder,—cycle $\frac{1}{3}$; 91, leafy branch of cherry,—cycle $\frac{2}{5}$.

case of the subsequent development of the branch, as often occurs in the Berberis and larch, their spiral arrangement becomes manifest. In the pines the fascicles have fewer leaves, their number being definite and characteristic of the species. Thus P. strobus, the white pine, has 5 leaves in each fascicle, P. palustris, the long-leaved pine, has 3, P. inops, 2.

226. THE OPPOSITE LEAVED TYPE is also spiral. The leaves in each circle, whether two or more, are equidistant, dividing the circumference of the stem into equal arcs. The members of the second circle are not placed directly above those of the first, but are turned, as it were, to the right or left, so as to stand over the intervening spaces. Hence there may be traced as many spirals as there are leaves in each whorl.

227. DECUSSATE LEAVES result from this law, as in the motherwort and all the mint tribe, where each pair of opposite leaves crosses in direction the next pair, forming four vertical rows of leaves. Therefore, it is

228. AN ESTABLISHED LAW that the course of development in the growing plant is universally spiral. But this, the *formative cycle* as it is called, has several variations.



92, 93, 94, showing the course of the spiral thread and the order of the leaf-succession in the axes of elm, alder, and cherry. 95, axis of Osage-orange with a section of the bark peeled, displaying the order of the leaf-scars (cycle $\frac{3}{8}$).

229. THE ELM CYCLE. In the strictly alternate arrangement (elm, linden, grasses) the spiral thread makes one complete circuit and commences a new one at the third leaf. The third leaf stands over the first, the fourth over the second, and so on, forming two vertical rows of leaves. Here (calling each complete circuit a *cycle*) we observe

230. FIRST, That this cycle is composed of two leaves; second, that the angular distance between its leaves is $\frac{1}{2}$ a cycle (180°); third, if we express this cycle mathematically by $\frac{1}{2}$, the numerator (1) will denote the turns or revolutions, the denominator (2) its leaves, and the fraction itself the angular distance between the leaves ($\frac{1}{2}$ of 360°).

231. THE ALDER CYCLE. In the alder, birch, sedges, &c., the cycle is not complete until the fourth leaf is reached. The fourth leaf stands over the first, the fifth over the second, &c., forming three vertical rows. Here call the cycle $\frac{1}{3}$; 1 denotes the turns, 3 the leaves, and this fraction itself the angular distance ($\frac{1}{3}$ of 360°).

232. THE CHERRY CYCLE. In the cherry, apple, peach, oak, willow, etc., neither the third nor the fourth leaf, but the *sixth*, stands over the first; and in order to reach it the thread makes two turns around the stem. The sixth leaf is over the first, the seventh over the second, &c., forming five vertical rows. Call this the $\frac{2}{5}$ cycle; 2 denotes the turns, 5 the leaves in the cycle, and the fraction itself the angular distance ($\frac{2}{5}$ of 360°).

233. THE OSAGE-ORANGE CYCLE. In the common hedge plant, Osage-orange, the holly, evening primrose, flax, etc., we find no leaf exactly over the first until we come to the 9th, and in reaching it the spiral makes three turns. Here the leaves form eight vertical rows. It is a $\frac{3}{8}$ cycle; 3 the number of turns, 8 the number of leaves, and the fraction the angular distance between the leaves ($\frac{3}{8}$ of 360°).

234. THE CYCLES COMPARED. These several fractions which represent the above cycles form a series as follows: $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, in which each term is the sum of the two preceding. The fifth terms in order will, therefore, be $\frac{5}{13}$; and this arrangement is actually realized in

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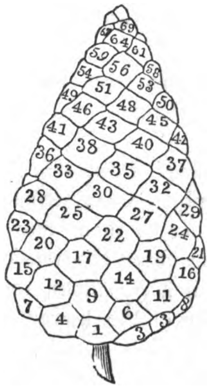

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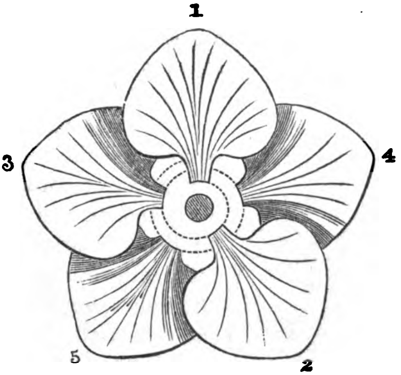


96, Phyllotaxy of the cone (cycle $\frac{8}{21}$) of Pinus serotina. 97, cherry cycle ($\frac{2}{5}$), as seen from above, forming necessarily that kind of æstivation called quincuntial.

235. THE WHITE PINE CYCLE. In the young shoots of the white pine, in cones of most pines, in flea-bane (Erigeron Canadense), etc., the fourteenth leaf stands over the first, the fifteenth over the second, etc. The spiral thread makes five revolutions to complete the cycle, which is, therefore, truly expressed by $\frac{5}{13}$.

236. THE HOUSELEEK CYCLE is next in order, expressed by the fraction $\left(\frac{3+5}{8+13}\right)$ $\frac{8}{21}$ having eight turns and twenty-one leaves. Examples are found in the Scotch pine, houseleek, &c.

237. HOW TO DETERMINE THE HIGHER CYCLES. To trace the course of the formative spiral in these higher cycles becomes difficult on account of the close proximity of the leaves. In the pine cone (Fig. 96, Pinus serotina) several sets of secondary spirals are seen; one set of five parallel spirals turning right (1—6—11—16,

etc., the common difference being also five); two sets (one of three, the other of eight) turning left; and still another set, of thirteen, steepest of all, turning right (1—14—27, etc.). *Now the sum of the spirals contained in the two steepest sets gives the denominator of the fraction expressing the true formative spiral sought.* Thus, 8+13=21. The numerator corresponding is already known, and the fraction is $\frac{8}{21}$. See also the white pine cone, whose cycle is $\frac{5}{13}$.

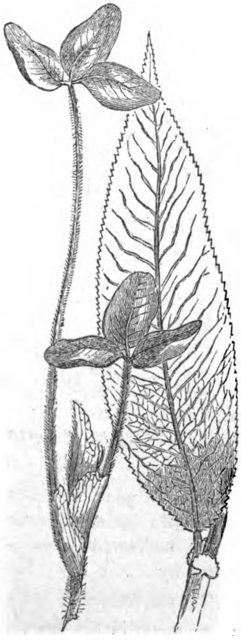
238. Diagram 97 represents the leaves of a cherry cycle as seen from above, and verified in the æstivation of the flowers in the rose-family.

MORPHOLOGY OF THE LEAF.

239. General character. The leaf may be regarded as an expansion of the substance of the bark, extended into a broad thin plate by means of a woody frame work or skeleton, issuing from the inner part of the stem. The expanded portion is called the lamina or blade of the leaf, and it is either *sessile*, that is, attached to the stem by its base, or it is *petiolate*, attached to the stem by a footstalk called the petiole.

240. Stipules. But the regular petiole very often bears at its base a pair of leaf-like appendages, more or less apparent, called *stipules*. Leaves so appendaged are said to be *stipulate*, otherwise they are *exstipulate*.

98 99



98. Leaf of willow (Salix lucida); *s*, the stipules. The midvein is 3-lined; veinlets 2-lined; veinulets single-lined. 99, clover leaves; *s*, stipules, *p*, petiole, *l*, leaflets.

241. Therefore a complete leaf consists of three distinct parts; the lamina or blade, the petiole, and the stipules.

242. Transformations. Both the petiole, blade and stipules are subject to numerous modifications of form. Either of them may exist without the others, or they may all be transformed into other organs, as pitchers, spines, tendrils, and even into the organs of the flower, as will hereafter appear.

OF THE PETIOLE.

243. The form of the distinct petiole is rarely cylindrical, but more generally flattened or *channeled* on the upper side. When it is flattened in a vertical direction, it is said to be *compressed*, as in the aspen or poplar. In this case the blade is very unstable, and agitated by the least breath of wind.

244. The winged petiole is flattened or expanded into a margin, but laterally instead of vertically, as in the asters. Sometimes the

margins outrun the petioles, and extend down the stem, making that winged or *alate* also. Such leaves are said to be *decurrent* (*decurro*, run down). Ex. Mullein.

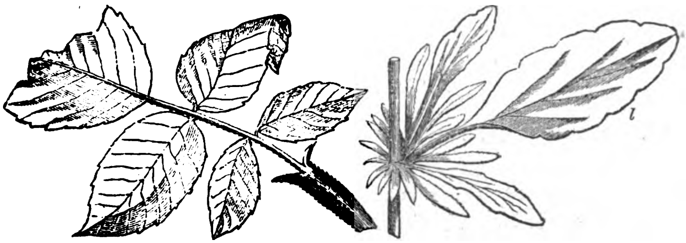
245. The amplexicaul or stem-clasping petiole is dilated at the base into a margin which surrounds or clasps the stem, as in the umbilifers. Frequently we find the stem-clasping margins largely developed, constituting a *sheath*—with free edges in the grasses, or closed into a tube in the sedges.

246. The petiole is simple in the simple leaf, but compound or branched in the compound leaf, with as many branches (petiolules) as there are divisions of the lamina.

OF THE STIPULES.

247. Stipules are certain leaf-like expansions, always in pairs, situated one on each side of the petiole near the base. They do not occur in every plant, but are pretty uniformly present in each species of the same natural order. In substance and color they usually resemble the leaf, sometimes they are colored like the stem, often they are membranous and colorless. In the palmetto its substance is a coarse net-work resembling canvass.

100 101

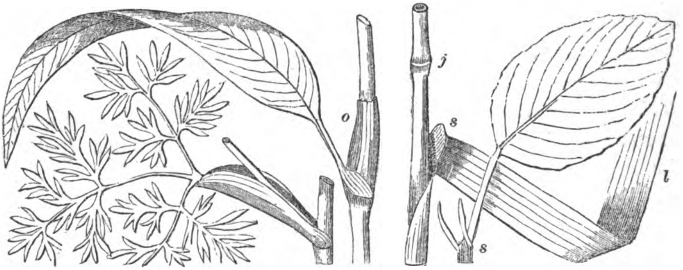


100, Rose leaf, odd-pinnate, with adnate stipules. 101, Violet, (V. tricolor), with simple leaf (*l*), and free compound stipules.

248. Stipules are often adnate or adherent to the petiole, as in the rose; more generally they are free, as in the pea and pansy. In these cases and others they act the part of leaves; again they are very small and inconspicuous.

249. An ochrea is a membranous sheath inclosing the stem from the node upwards, as in the knot-grass family (Polygonaceæ). It is formed of the two stipules cohering by their two margins. In case the two stipules cohere by their outer margin only, a double stipule is formed opposite to the leaf, as in the button-wood. If they cohere by their inner margin, the double stipule appears in the leaf axil, as in the pond-weed (Potamogeton).

250. **Inter-petiolar stipules** occur in a few opposite leaved tribes, as the Galium tribe. Here we find them as mere bristles in Diodia while in Galium they look like the leaves, forming whorls. Such whorls, if complete, will be apparently 6-leaved, consisting of two true leaves and four stipules. But the adjacent stipules are often united, and the whorl becomes 4-leaved.



102 103 104 105

102, Leaf of Conioselinum, tripinnate, with sheathing petiole. 103, Leaf of Polygonum Pennsylvanicum, with its (*o*) ochrea. 104, Culm of grass, with joint (*j*), leaf (*l*) ligule (*s*). 105, Leaf of pear-tree, with slender stipules.

251. **The Ligule** of grasses is generally regarded as a double axillary stipule. The leaflets of compound leaves are sometimes furnished with little stipules, called *stipels*.

252. **Stipules are often fugacious**, existing as scales in the bud, and falling when the leaves expand, or soon after, as in the Magnolia and tulip-tree.

OF THE VEINS.

253. **Leaves, simple and compound.** A leaf is *simple* when its blade consists of a single piece, however cut, cleft or divided; and *compound* when it consists of several distinct blades, supported by as many branches of a compound petiole.

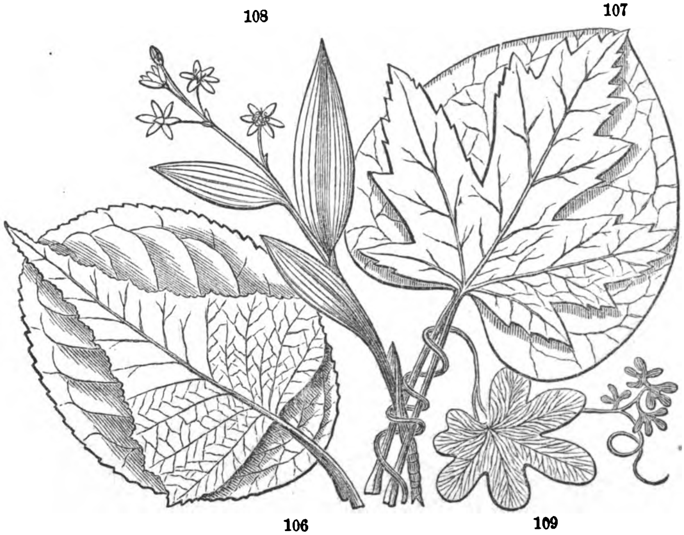
254. **Nature of veins.** The blade of the leaf consists of, (1) the *frame-wovk*, and (2) the tissue commonly called the *parenchyma*. The frame-work is made up of the branching vessels of the foot-stalk, which are woody tubes pervading the parenchyma, and conveying nourishment to every part. Collectively, these vessels are called *veins*, from the analogy of their functions.

255. **Venation** is a term denoting the manner in which the veins are divided and distributed. The several organs of venation, differing from each other only in size and position, may be termed the midvein, veins, veinlets and veinulets. (The old terms, *midrib* and *nerves*, being anatomically absurd, are here discarded).

256. **The midvein** is the principal axis of the venation, or prolongation of the petiole, running directly through the lamina, from base to

apex, as seen in the leaf of the oak or birch. If there be several similar divisions of the petiole, radiating from the base of the leaf, they are appropriately termed *veins;* and the leaf is said to be three-veined, five-veined, etc. Ex. maple.

257. The primary branches sent off from the midvein, or the veins we may term the VEINLETS, and the secondary branches, or those sent off from the veinlets, are the VEINULETS. These also branch and subdivide until they become too small for vision.



Varieties of venation. 106, feather-veined,—leaf of Betula populifolia (white birch), lying upon a leaf of plum-tree; same venation with different outlines. 107, Palmate-veined,—leaf of white maple, contrasted with leaf of Circis Canadensis. 108, Parallel venation,—plant of "three-leaved Solomon's-seal," (Asteranthemum trifoliatum *Kunth.*) 109, Forked venation,—climbing fern (Lygodium).

258. MODES OF VENATION. Botanists distinguish three principal modes of venation, which are in general characteristic of the three grand divisions of the vegetable kingdom already noticed.

RETICULATE, OR NET-VEINED, as in the Exogens: this kind of venation is characterized by the frequent reunion or inosculation of its numerously branching veins, so as to form a kind of irregular net-work.

PARALLEL-VEINED, as in the Endogens. The veins, whether straight or curved, run parallel, or side by side, to the apex of the leaf, or to the margin, and are always connected by simple transverse veinlets.

FORK-VEINED, as in the ferns (and other Cryptogamia, where veins are present at all). Here the veins divide and subdivide in a furcate manner, and do not re-unite.

259. Of the *reticulate* venation, the student should carefully note three leading forms, the feather-veined, the palmate-veined, and the triple-veined.

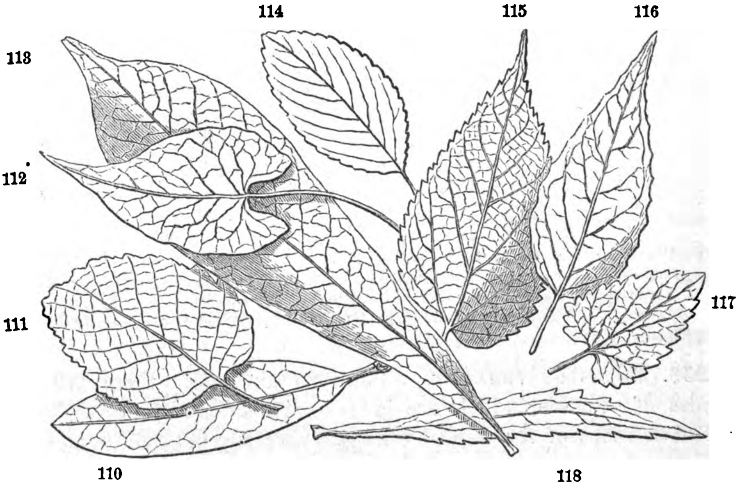
THE FEATHER-VEINED (pinni-veined) leaf is that in which the venation consists of a midvein giving off at intervals lateral veinlets and branching veinulets. Ex. beech, chestnut.

260. IN THE RADIATE-VEINED (palmi-veined) leaf the venation consists of several veins of nearly equal size, radiating from the base towards the circumference, each with its own system of veinlets. Ex. maple, crow-foot.

261. THE TRIPLI-VEINED seems to be a form intermediate between the two others when the lowest pair of veinlets are conspicuously stronger than the others above them towards the apex, extending with the midvein towards the summit.

262. IN PARALLEL-VEINED venation the veins are either *straight*, as in the linear leaf of the grasses, *curved*, as in the oval leaf of the orchis, or *transverse* as in the Canna, Calla, &c.

FORM OR FIGURE.

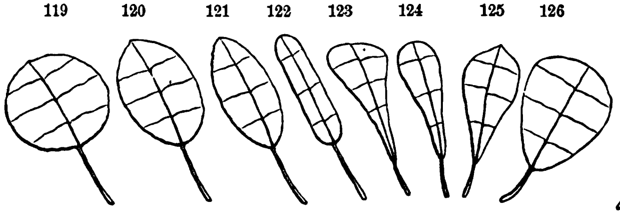


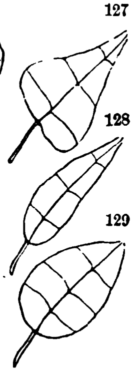
Forms of leaves. 110, Rhododendron maximum. 111, Alnus glutinosa (cult.). 112, Polygonum sagittatum. 113, Pawpaw. 114, Impatiens fulva. 115, Celtis Americana. 116, Circaea Lutetiana. 117, Catmint. 118, Solidago Canadensis—a triple-veined leaf.

263. THAT INFINITE VARIETY of beautiful and graceful forms for which the leaf is distinguished becomes intelligible to the student only when viewed in connection with its venation. Since it is through the veins alone that nutriment is conveyed for the development and extension of the parenchyma, it follows that there will be the greatest extension of *outline* when the veins are largest and most numerous. Consequently the form of the leaf will depend upon the direction of the veins and the vigor of their action in developing the intervening tissue. In our description

of individual forms of outline we shall select only the most remarkable, leaving others for explanation in the glossary.

264. THE MOST OBVIOUS ARRANGEMENT is that which is founded upon the modes of veining; but it should be premised that different forms of venation often give rise to the same outline. Were we required to characterize our idea of the abstract, typical leaf-form, we should sketch an oval outline of surface, with equal sides and unequal ends. The nearest approach to this we find among the





Diagrams of pinnate-veined leaf-forms.

119, orbicular,
120. oval,
121, elliptical,
122, oblong,
123, cuneiform.
124, spathulate,
125, oblanceolate,
126, obovate,
127, deltoid,
128, lanceolate,
129, ovate.

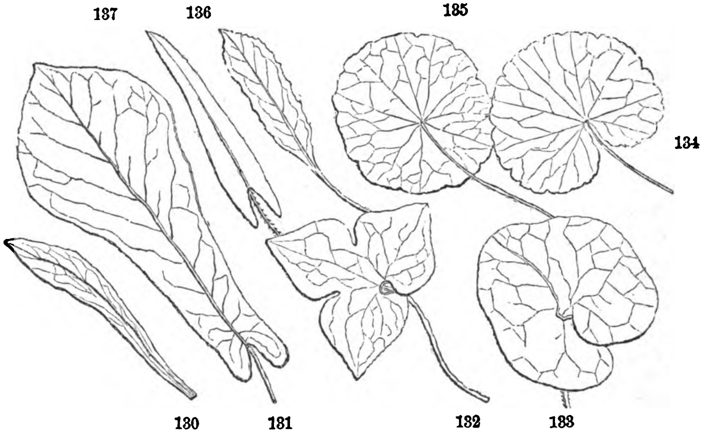
265. FEATHER-VEINED LEAVES. Of these, the following forms depend upon the length of the veinlets in relation to each other and to the midvein. *When the lower veinlets are longer* than the others, the form of the blade will be (1) *ovate*, with the outline of an egg, the broad end at the base; (2) *lanceolate*, or lance-shaped, narrower than ovate, tapering gradually upwards; (3) *deltoid* or triangular-shaped, like the Greek letter Δ.

a. IF THE MIDDLE VEINLETS EXCEED the others in length, the leaf will be (4) orbicular, roundish or quite circular; (5) *elliptical*, with the outline of an ellipse, nearly twice longer than broad; (6) *oval*, broadly elliptical; (7) *oblong*, narrowly elliptical.

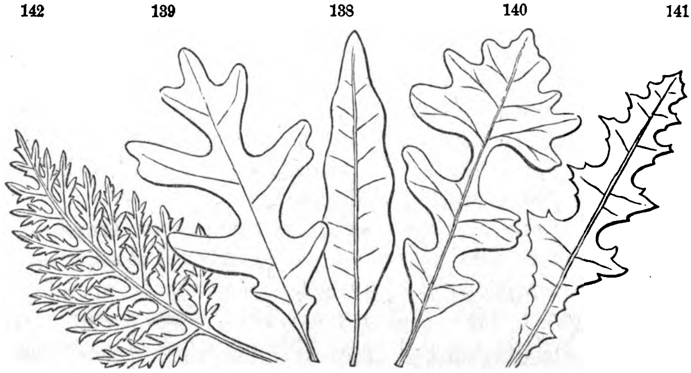
266. WHEN THE VEINLETS ARE MORE LARGELY DEVELOPED IN THE UPPER REGION OF THE LEAF its form becomes (8) *obovate*, inversely ovate, the narrow end at base; (9) *oblanceolate*, that is, lanceolate with the narrow end at base; (10) *spatulate*, like a spatula, with a narrow base and a broader, rounded apex; (11) *cuneate* or *cuneiform*, shaped like a wedge with the point backwards.

267. AGAIN, IF THE LOWEST PAIR OF VEINLETS ARE LENGTHENED AND MORE OR LESS RECURVED, the leaf will be variously modified in respect to its base, becoming (12) *cordate*, or heart-shaped, an ovate outline with a sinus or reëntering angle at base; (13) *auriculate*, with ear-shaped lobes at base; (14) *sagittate*, arrow-shaped, with the lobes pointed, and directed backwards; (15) *hastate*, halbert-shaped, the lobes directed outwards.

268. Pinnatifid forms. The following pinnate-veined forms, approaching the compound leaf, depend less upon the proportion of the veinlets than upon the relative development of the intervening tissue. The prefix *pinnated* is obviously used in contrast with *palmated* among palmate-veined forms.



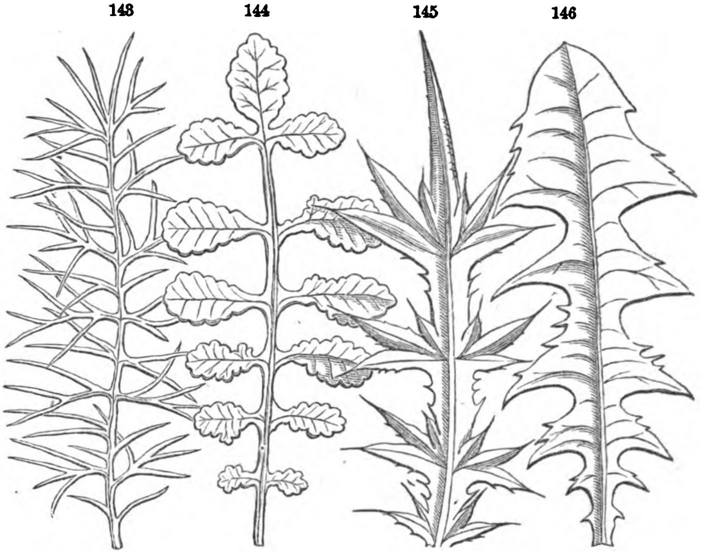
Forms of leaves. 130, Silene Virginica. 131, Magnolia Fraseri. 136, Arabis dentata. 137, Polygonum arifolium. 132, Hepatica acutiloba. 133, Asarum Virginicum. 134, Hydrocotyle Americana. 135, H. umbellata.



Feather-veined leaves, approaching the compound. 138, Quercus imbricaria—undulate. 139, Q. alba (white oak)—lobate-sinuate. 140, Q. macrocarpa—lyrate. 141, Mulgedium (milk-weed). 142, Bipinnatifid leaf of Ambrosia artemisifolia (hog-weed).

269. Pinnatifid (*pinna*, feather, *findo*, to cleave) feather-cleft, the tissue somewhat sharply cleft between the veinlets about half way to the midvein, forming oblong segments. When the segments of a pinnatifid leaf are pointed and curved backward it becomes *runcinate*, *i. e.*, re-uncinate. When the terminal segment of a pinnatifid leaf is

orbicular in figure and larger than any other, presenting the form of the ancient lyre, the form is termed *lyrate.*



Feather-veined leaves almost compound. 143, Nigella (pinnatisect). 144, Cheledonium majus. 145, Thistle (Cirsium lanceolatum). 146, Dandelion (runcinate-lyrate).

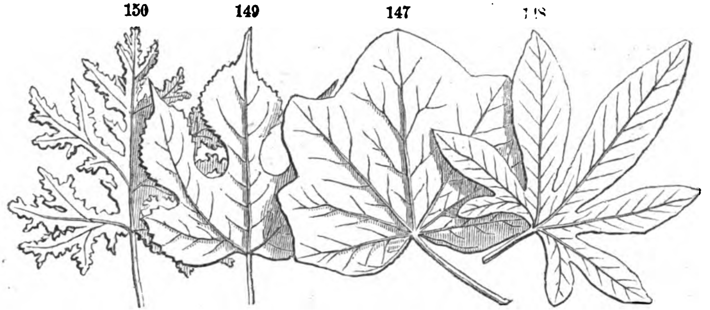
270. **Pinnately parted** implies that the incisions are deeper than *pinnatifid*, nearly reaching the midvein. In either case the leaf is said to be *sinuate* when the incisions (sinuses) as well as the segments are rounded and flowing in outline. Such segments are *lobes*, and the leaves *lobate* or *lobed*, a very generic term.

271. **The palmate venation** presents us with a set of forms which are, in general, broader in proportion than the pinnate, having the breadth about equaling the length. Such a leaf may be rarely ***broadly ovate*** or ***broadly cordate***, terms which require no further explanation. Or it may be

Reniform, kidney-shaped, having a flowing outline broader than long, concave at base; or

Peltate, shield-form, the petiole not inserted at the margin but in the midst of the lower surface of the blade. This singular form evidently results from the blending of the base lobes of a deeply cordate leaf, as seen in hydrocotyle. It may be orbicular, oval, etc.

272. **Palmate forms.** The following result from deficiency of tissue, causing deep divisions between the veins. Leaves thus dissected are said to be *palmately-lobed* when either the segments or the sinuses are somewhat rounded and continuous. The number of lobes is denoted by such terms as ***bilobate***, ***trilobate***, ***five-lobed***, etc.



Palmate-veined leaves. 147, Menispermum Canadense. 148, Passiflora cerulea. 149, Broussonetia papyrifera. 150, Oak geranium.

Leaves are *palmately cleft* and *palmately parted*, according to the depth of the incisions as above described. But the most peculiar modification is

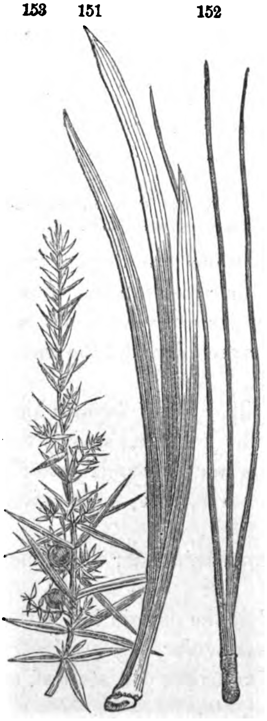
273. THE PEDATE, like a bird's foot, having the lowest pair of veinlets enlarged, recurved, and bearing each several of the segments (148).

274. THE FORMS OF THE PARALLEL-VEINED LEAVES are remarkable for their even, flowing outlines, diversified solely by the direction and curvature of the veins. When the veins are straight the most common form is

275. THE LINEAR, long and narrow, with parallel margins, like the leaves of the grasses—a form which may also occur in the pinnate-veined leaf, when the veinlets are all equally shortened. The *ensiform*, or sword-shaped, is also linear, but has its edges vertical, that is, directed upward and downward.

276. IF THE VEINS CURVE, we may have the *lanceolate*, *elliptical*, or even *orbicular* forms; and if the lower curve downward, the *cordate*, *sagittate*, etc., all of which are shown in the cuts.

The palmate or radiate form is finely illustrated in the palmetto and other palms, whose large, fan-shaped leaves are appropriately termed *flabelliform* (fan-shaped).



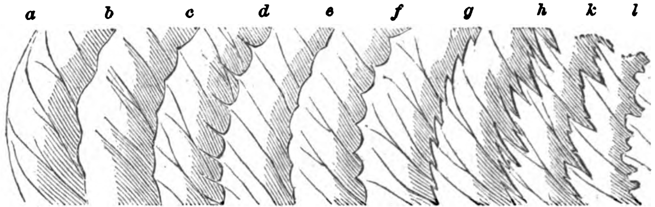
151, Ensiform leaves of iris. 152, Acerose leaves of pinus. 153, Subulate leaves of Juniperus communis.

277. THE LEAVES OF THE PINE AND THE FIR TRIBE (Coniferæ) generally are parallel-veined also, and remarkable for their contracted

forms, in which there is no distinction of petiole or blade. Such are the *acerose* (needle-shaped) leaves of the pine, the *subulate* (awl-shaped) and scale-form leaves of the cedars, etc.

MARGIN.

The following terms apply to the various modifications of the margin, as such, not affecting the general outline of the leaf.



154. Diagram of leaf-margins. *a*, entire; *b*, undulate; *c*, repand; *d*, spinous; *e*, crenate; *f*, dentate; *g*, serrate; *h*, laciniate; *k*, incised; *l*, erose.

278. **Entire**, even edged, having the tissue completely filled out. Sometimes a vein runs along the margin, which might otherwise be easily torn, as in the Caladium. But when the marginal tissue is deficient, the leaf becomes

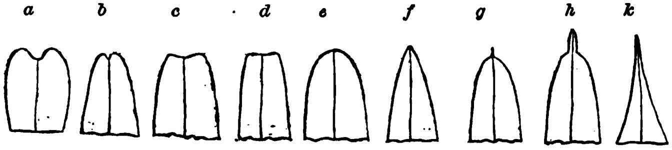
279. **Dentate**, having sharp teeth pointing outward from the centre; *serrate*, with sharp teeth pointing forwards, like the teeth of a saw; *crenate*, with rounded or blunt teeth. The terms *denticulate*, *serrulate*, *crenulate*, denote finer indentations of the several kinds; *doubly dentate*, &c., denote that the teeth are themselves toothed.

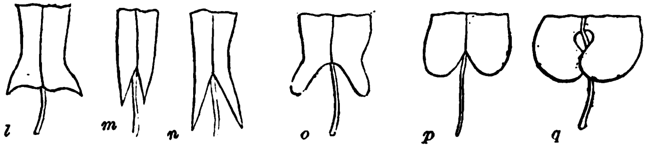
280. **The undulate**, or wavy edge is somewhat different from the *repand*, which bends like the margin of an umbrella. If the veins project, and are tipped with spines, the leaf becomes *spinous*.

281. **Irregularly divided margins** are said to be *erose* or jagged, *laciniate* or torn, *incised* or cut.

282. **Crisped.** Often, instead of a deficiency there is a superabundance of marginal tissue, denoted by the term *crispate* or crisped.

APEX.





155, Apex of leaves. *a*, obcordate; *b*, emarginate; *c*, retuse; *d*, truncate; *e*, obtuse; *f*, acute; *g*, mucronate; *h*, cuspidate; *k*. acuminate.

156. Bases of leaves. *l*, hastate; *m*, *n*, saggittate; *o*, auriculate; *p*, cordate; *q*, reniform.

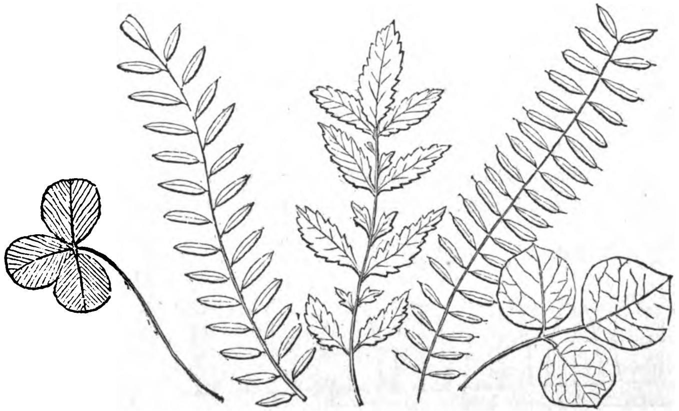
283. **Pointed leaves.** In regard to the termination of a leaf at its apex, it may be *acuminate*, ending with a long, tapering point; *cuspidate*, abruptly contracted to a sharp, slender point; *mucronate*, tipped with a spiny point; *acute*, simply ending with an angle; *obtuse*, rounded at the point.

284. **Pointless leaves.** Or the leaf may end without a point, being *truncate*, as if cut square off; *retuse*, with a rounded end slightly depressed where the point should be; *emarginate*, having a small notch at the end; *obcordate*, inversely heart-shaped, having a deep indentation at the end.

OF THE COMPOUND LEAF.

285. **Theory.** If we conceive of a *simple* leaf becoming a *compound* one, on the principle of "deficiency of tissue between the veins," it will be evident that the same forms of venation are represented by the branching petioles of the latter as by the veins of the former. The number and arrangement of the parts will therefore in like manner correspond with the mode of venation.

286. **Leaflets.** The divisions of a compound leaf are called *leaflets*, and the same distinction of outline, margin, &c., occur in them as in simple leaves. The *petiolules* of the leaflets may or may not be articulated to the main petiole, or *rachis*, as it is called.

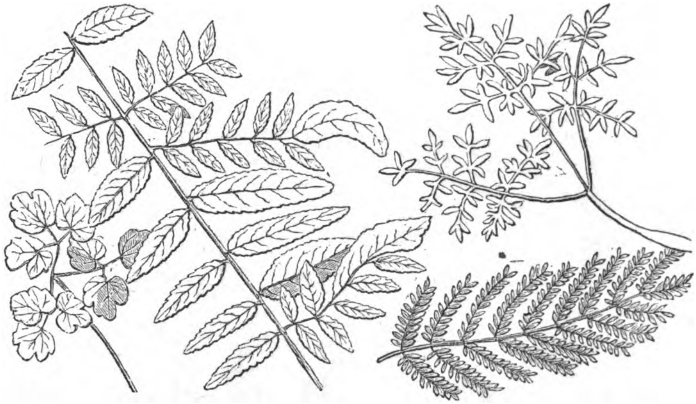


Compound leaves. 157, Trifolium repens. 158, Desmodium rotundifolium. 160, Glotidium. 161, Cassia. 159, Agrimonia.

287. **Pinnately compound.** From the pinnate-veined arrangement we may have the *pinnate* leaf, where the petiole (midvein) bears a row of leaflets on each side, either sessile or *petiolulate*, generally equal in

number and opposite. It is *unequally pinnate* when the rachis bears an odd terminal leaflet, and *equally pinnate* when there is no terminal leaflet, and interruptedly pinnate when the leaflets are alternately large and small (159, etc).

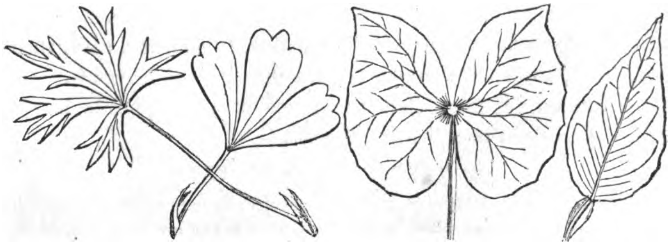
288. THE NUMBER OF LEAFLETS IN THE PINNATE LEAF varies from thirty pairs and upwards (as in some acacias), down to *three*, when the leaf is said to be *ternate* or *trifoliate;* or *two*, becoming *binate*, or finally even to *one* leaflet in the lemon. Such a leaf is theoretically compound, on account of the leaflet (blade) being articulated to the petiole.



Compound leaves. 162, Clematis. 163, Erigenia bulbosa. 164, Acacia. 165, Honey-locust.

289. A BIPINNATE LEAF (twice pinnate) is formed when the rachis bears *pinnæ* or secondary pinnate leaves, instead of leaflets, and *tripinnate* (thrice pinnate), when pinnæ take the places of the leaflets of a bipinnate leaf. When the division is still more complicated the leaf is *decompound.*

290. TRANSITION LEAVES. Different degrees of division often exist in different parts of the same leaf, illustrating the gradual transition of leaves from simple to



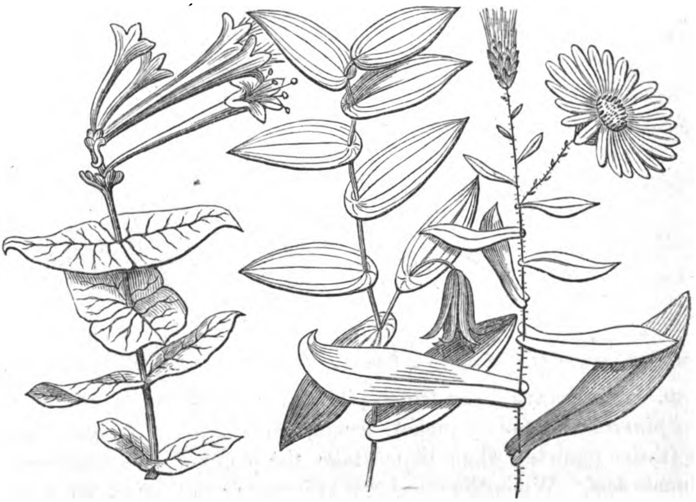
167, Lemon. 168, Jeffersonia. 169, Potentilla anserina. 166, P. tridentata.

compound in all stages. The leaves of the honey-locust and coffee tree (Gymnocladus) often afford curious and instructive examples.

291. A **biternate leaf** is formed when the leaflets of a ternate leaf give place themselves to ternate leaves, and *triternate* when the leaflets of a biternate leaf again give place to ternate leaves.

292. **Palmately compound. A distinction.** The palmate venation has also its peculiar forms of compound leaves, as *ternate*, quinate, septinate, etc., according to the number of leaflets which arise together from the summit of the petiole. *Ternate* leaves of this venation are to be carefully distinguished from those of the *pinnate* plan. The *palmately ternate* leaf consists of three leaflets, which are either all sessile or stalked alike; the *pinnately ternate* has the terminal leaflet raised above the other two on the prolonged rachis (157, 158).

172 171 170



Insertion of leaves. 170, Aster oblongifolius? (amplexicaul). 171, Uvularia perfoliata. 172, Lonicera sempervirens, (connate).

With regard to the insertion the leaf is said to be

293. **Amplexicaul,** when its base lobes adhere to and clasp the stem. Should these lobes extend quite around the stem and become blended together, on the other side a *perfoliate* leaf will be formed (*per*, through, *folium*, leaf), the stem seeming to pass through the leaves.

294. **Connate** denotes that the bases of two opposite leaves are united so as to form one piece of the two.

OF TEXTURE AND SURFACE.

In descriptive botany it is also needful to regard the variations of leaves in the above respects. The terms which we briefly notice below are equally applicable to any other organs.

295. IN TEXTURE leaves may be *membranous*, or *coriaceous* (leathery), or *succulent* (fleshy), or *searious* (dry), *rugous* (wrinkled), &c., which terms need only to be mentioned.

296. IN THE QUALITY OF SURFACE, the leaf may be *glabrous* (smooth), destitute of all hairs, bristles, &c., or *scabrous* (rough), with minute, hard points, hardly visible.

297. A DENSE COAT OF HAIRS will render the leaf *pubescent* when the hairs are soft and short; *villous* when they are rather long and weak; *sericeous*, or silky, when close and satin-like; such a coat may also be *lanuginous*, woolly; *tomentous*, matted like felt; or *floccose*, in soft, fleecy tufts.

298. THINLY SCATTERED HAIRS render the surface *hirsute* when they are long; *pilous* when short and soft; *hispid* when short and stiff. The surface will be

299. SETOUS, when beset with bristly hairs called *setae*; and *spinous* when beset with spines, as in the thistle and horse-nettle. Leaves may also be armed with *stinging* hairs which are sharp and tubular, containing a poisonous fluid, as in nettles and Jatropha stimulans.

300. A PRUINOUS surface is covered with a bluish-white waxy powder, called *bloom*, as in the cabbage, and a punctate leaf is dotted with colored points or pellucid glands.

301. DOUBLE TERMS. The modifications of leaves are almost endless. Many other terms are defined in the glossary, yet it will be found often necessary in the exact description of a plant to combine two or more of the terms defined in order to express some intermediate figure or quality; thus *ovate-lanceolate*, signifying a form between ovate and lanceolate, etc.

302. SUB. The Latin preposition *sub* (under) prefixed to a descriptive term denotes the quality which the term expresses, in a lower degree, as *subsessile*, nearly sessile, *subserrate*, somewhat serrate.

CHAPTER VIII.

TRANSFORMATIONS OF THE LEAF.

Hitherto we have considered the leaf as foliage merely—constituted the fit *organ* of aëration by its large expansion of surface. This is indeed the chief, but not the only aspect in which it is to be viewed.

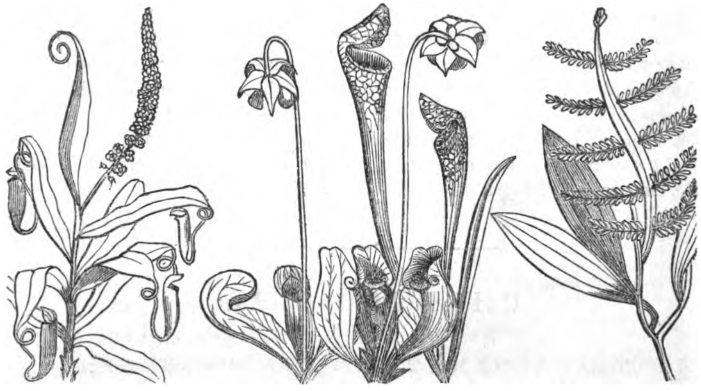
303. THE LEAF IS A TYPICAL FORM, that is, the type or idea from which the Divine Architect derived the form of every other appendage of the plant. To trace out this idea in all the disguises under which it lurks is one of the first aims of the botanist. Several of these forms of disguise have already been noticed, *e. g.*

304. The scales which clothe the various forms of scale-stems are leaves, or more usually *petioles*, reduced and distorted, perhaps by the straitened circumstances of their underground growth. The scales of corms and rhizomas are mostly mere membranes, while those of the bulb are fleshy, serving as depositories of food for the future use of the plant. That these scales are leaves is evident, 1st, from their position at the nodes of the stem, 2d, from their occasional development into true leaves.

305. Bud scales. The brown scales which cover winter buds are of the same nature and origin.

306. The cotyledons of seeds or seed-lobes are readily recognized as leaves, especially when they arise above ground in germination, and form the first pair upon the young plant, as in the beech-nut and squash seed. Their deformity is due to the starchy deposits with which they are crammed for the nourishment of the embryo when germinating, and also to the way in which they are packed in the seed.

307. Phyllodia are certain leaf-forms, consisting of petioles excessively compressed, or expanded vertically into margins, while the true lamina is partly or entirely suppressed. Fine examples are seen in our greenhouse acacias from Australia. Their vertical or edgewise position readily distinguishes them from true leaves.



Ascidia. **173, Nepenthes.** **174, Sarracenia psittacina.** **175, S. purpurea.** **176, S. Gronovii, β. Drummondii.** **177, Acacia heterophylla, its phyllodia.**

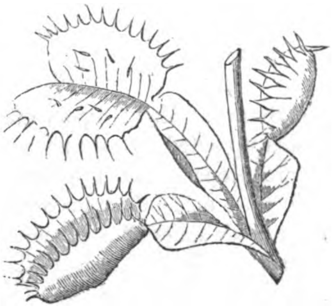
308. Ascidia or pitchers, are surprising forms of leaves, expressly contrived, as if by art, for holding water. The pitchers of Sarracenia, whose several species are common in bogs North and South, are evidently formed by the blending of the involute margins of the broadly winged petioles, so as to form a complete vase. The broad expansion which appears at the top may be regarded as the lamina. These pitchers contain water, in which insects are drowned, being prevented from escaping by the deflexed hairs at the mouth.

309. **Nepenthes.** The greenhouse pitcher-plant is a native of the East Indies. Its proper leaves are sessile and lanceolate. The midvein extends beyond the apex like a tendril, to the length of six or eight inches. The extremity of this tendril is inflated into a hollow vessel, similar to a pitcher, and usually contains about half a pint of pure water. It is furnished with a leafy lid connected to it by a ligament which expands or contracts according to the state of the atmosphere, so that the cap is open in damp weather and closed in dry.

310. **Dischidia.** Another wonderful provision of this kind is observed in a plant growing in the forests of India, called Dischidia. It is a twining plant, ascending the tall trees to the distance of a hundred feet from its roots, and destitute of leaves except near its top. The pitchers seem formed of a leaf with its edges rolled inward and adherent, and its upper end or mouth is open to receive whatever moisture may descend into it. But the greatest marvel in its structure is that several bundles of absorbent fibres, resembling roots, are sent out from the nearest parts of the stem, enter the pitchers, and spread themselves through the cavity.

311. **Air bladders.** Many weak-stemmed water plants are furnished with little sacks filled with air to buoy them up near to the surface. Such are the bladders of the common bladderwort, formed from the leaf lobes. In the horned-bladderwort the floats are made of the six upper inflated petioles lying upon the surface of the water like a wheel-shaped raft, and sustaining the flower upon its own elevated stalk.

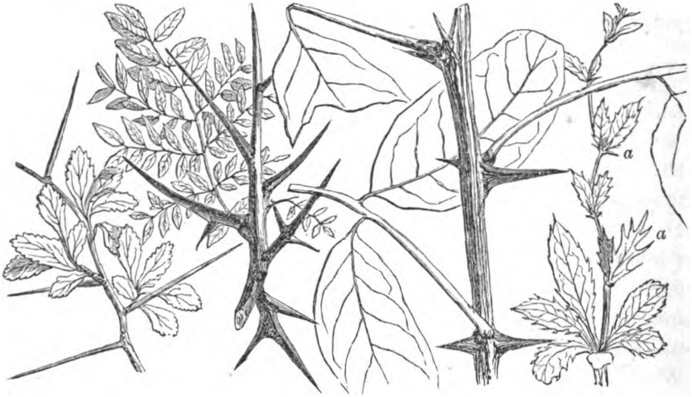
312. **The leaf of Venus' fly-trap** (Dionea), native of Carolina, is also of curious design. At the end of the leaf are two lobes bordered with spines. In the cavity between the lobes are several sharp points projecting upwards, and a gland which secretes a liquor attractive to insects. But when an unlucky fly, in search of food, alights upon it, the irritable lobes instantly close and impale him in their fatal embrace.


178, Leaves of Venus' fly-trap (Dionea).

313. **The Tendril** is a thread-like coiling appendage furnished to certain weak-stemmed plants as their means of support in place. Its first growth is straight, and it remains so until it reaches some object, when it immediately coils itself about it, and thus aquires a firm, though elastic hold. This beautiful appendage is finely exemplified in the Cucurbitaceæ and grape, above cited; also in many species of the pea tribe (Leguminosæ), when it is appended to the leaves. It is not a new organ, but some old one transformed and adapted to a new purpose. In Gloriosa superba the midvein of the leaf is prolonged beyond the blade into a coiling tendril. In the pea, vetch, etc., the tendrils represent the attenuated leaf blades themselves. Again, the entire leaf sometimes becomes a tendril in Lathyrus, while the stipules act as leaves.

314. **The petiole of the leaf of Clematis**, otherwise unchanged, coils like a tendril for the support of the vine. In the greenbriar, the stipules are changed to tendrils, which thus arise in pairs from the base of the petioles. So probably in the gourd tribe.

315. **But the tendrils of the grape-vine** are of a different nature. From their position opposite the leaves, and the tubercles occasionally seen upon them, representing flower buds, they are inferred to be abortive, or transformed flower-stalks.



179 180 181 182

Thorns. 179, Cratægus parvifolia (thorns axillary.) 180, Honey-locust. 181, Common locust. 182. Berberis, *a*, *a*, its thorns.

316. **Spines.** Many plants are armed, as if for self-defense, with hard, sharp-pointed, woody processes, called spines or thorns. Those which are properly called spines originate from leaves. In Berberis the spines are evidently transformed leaves, as the same plant exhibits leaves in every stage of the metamorphosis. In goat's-thorn (Astragalus tragacanthus) of S. Europe, the petioles change to spines after the leaflets fall off. In the locust (Robinia), there is a pair of spines at the base of the petiole, in place of stipules.

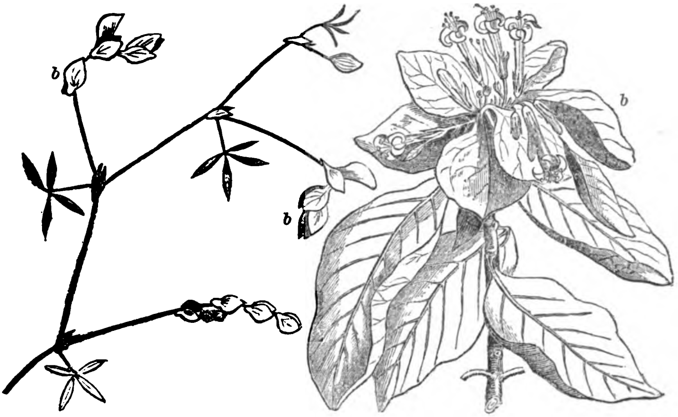
317. **Thorns** originate from axillary buds, and are abortive branches. This is evident from their position in the hawthorn and Osage orange. The apple and pear tree in their wild state produce thorns, but by cultivation become thornless, that is, the axillary buds, through better tillage, develop branches instead of thorns. The terrible branching thorns of the honey-locust originate just above the axil, from *accessory* buds.

318. **Prickles** differ from either spines or thorns, growing from the epidermis upon stems or leaves, at no determinate point, and consisting of hardened cellular tissue, as in the rose, bramble.

319. **Bracts.** By a more gentle transformation, leaves pass into bracts, which are those smaller, reduced leaf-forms situated near and among the flowers. So gradual is the transition from leaves to bracts

in the peony, *e. g.*, that no absolute limits can be assigned. Equally gradual is the transition from bracts to sepals of the flower—affording a beautiful illustration of the doctrine of metamorphosis. (374.)

Bracts will be further considered under the head of Inflorescence.



184 183

Bracts 183, Pinckneya pubens; *b*, colored bracts (reduced leaves). 184, Zornia tetraphylla; *b*, bracts (enlarged stipules).

CHAPTER IX.

INFLORESCENCE.

320. The functions of plant-life are two-fold, namely, vegetation and reproduction; the former looking to the preservation of the individual plant itself, the latter to the species. Corresponding with this view, there are also two classes of organs. Having considered the former class, that is, the organs of vegetation, we come now to the organs of reproduction, including the *flower*, the *fruit*, and the *seed*.

321. Inflorescence is a term denoting the arrangement of the flowers, and their position upon the plant.

322. Origin of flower buds. All the buds of a plant are supposed to be originally of one and the same nature, looking to the production of vegetative organs only. But at a certain period, a portion of the buds of the living plant, by an unerring instinct little understood, are converted from their ordinary intention into flower buds.

323. Proof of this theory. That this is the origin of the flower bud is evident from the known effects of cultivation, causing it to revert partly or wholly to its former intention, as in the *green rose*, when the petals, &c., all return to leaves; in

the *proliferous rose* when the axis grows on through the flower bearing leaves above it. In some instances the skillful gardener learns how to effect this interchange of nature in the buds at pleasure.

324. Hence in position and arrangement flower buds can not differ from leaf buds, and both are settled by the same unerring law which determines the arrangement of the leaves. Accordingly the flower bud is always found either *terminal* or *axillary.*

325. A single bud, whether terminal or axillary, may develop either a *compound inflorescence*, consisting of several flowers with their stalks and bracts, or a *solitary inflorescence*, consisting of a single flower.

326. The flower-bud is incapable of extension. While the leaf-bud may unfold leaf after leaf and node after node to an indefinite extent, the flower-bud blooms, dies, and arrests for ever the extension of the axil which bore it.

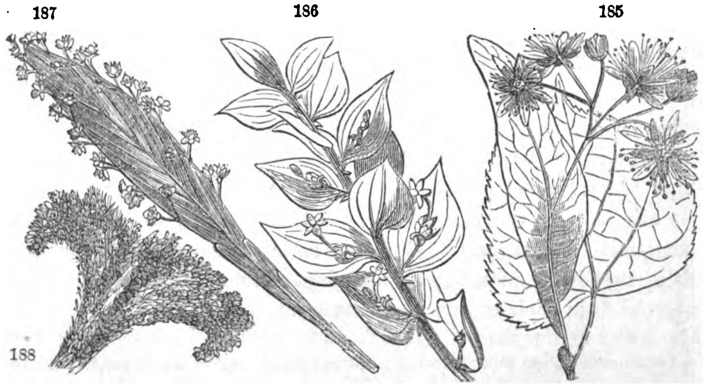
327. The peduncle is the flower-stalk. It bears no leaves, or at least only such as are reduced in size and changed in form, called *bracts.* If the peduncle is wanting the flower is said to be *sessile.*

328. The simple peduncle bears a single flower; but if the peduncle be divided into branches, it bears several flowers, and the final divisions bearing each a single flower, are called pedicels.

329. The scape is a flower-stalk which springs from a subterranean stem, in such plants as are called stemless or aculescent, as the primrose, tulip, blood-root. Like the peduncle it is leafless or with bracts only, and may be either simple or branched.

330. The rachis (ραχις, spine) is the axis of the inflorescence, or the main stem of the compound peduncle along which the pedicels are arranged.

331. The torus or receptacle is the end or summit of the flower-stalk.



Anomalous peduncles. 185, Linden-tree. 186, Butcher's-broom. 187, Xylophylla. 188, Coxcomb.

332. THE peduncle is subject to endless modifications. We find it sometimes excessively lengthened, again very short or wholly wanting; very slender or very thick. In coxcomb its branches are blended into a thick, fan-shaped mass; in butcher's-broom it expands into the form of a green leaf, and in the linden-tree into a seal-like bract. In Xylophylla it is foliaceous, bearing flowers along its margins.

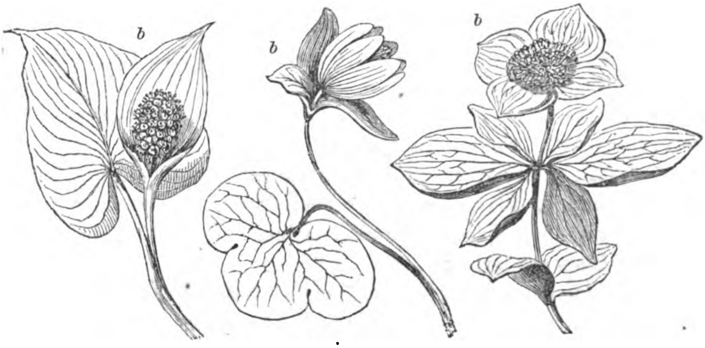
333. BRACTS. The branches of the inflorescence arise from the axils of reduced leaves, called *bracts.* These leaves, still smaller, growing upon the pedicels, are called *bracteoles.*

334. The bracts are usually simple in outline and smaller than the leaf, often gradually diminishing to mere points, as in Aster, or even totally suppressed, as in the Cruciferæ.

335. IN COLOR they are usually green, often colored, sometimes brilliantly, as in painted-cup. Sometimes they are scale-like, and again they are evanescent membranes.

336. THE SPATHE is a large bract formed in some of the monocotyledons, enveloping the inflorescence, and often colored as in the Arum, Calla, or membranous as in the onion and daffodil. Bracts also constitute an

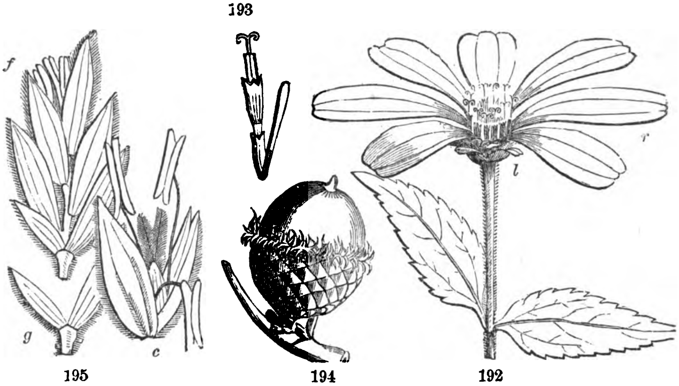
337. INVOLUCRE when they are collected into a whorl or spiral group. In the Phlox, Dodecatheon, and generally, the involucre is green, but sometimes colored and petaloid, as in dogwood and Euphorbia. Situated at the base of a compound umbel, it is called a *general* involucre, at the base of a partial umbel it is a *partial* involucre or *involucel,* both of which are seen in the umbelliferæ.



191 190 189

Bracts (*b*, *b*, *b*,). 189, Cornus Canadensis, with an involucre of 4 colored bracts. 190, Hepatica triloba, with an involucre of 3 green bracts. 191, Calla palustris, with a colored spathe of one bract.

338. IN THE COMPOSITÆ, where the flowers are crowded upon a common torus, forming what is called a *compound flower,* an involucre composed of many imbricated scales (bracts) surrounds them as a calyx surrounds a simple flower. The chaff also upon the torus are bracts to which each floret is axillary.



192, Helianthus grosse-serratus. *l*, involucre ; *r*, rays, or ligulate flowers ; 193, one of the disk flowers with its chaff-scale (bract). 194, Acorn of moss-cup oak (Q. macrophylla). 195, Poa pratensis ; *f*, spikelet entire, *g*, glumes, separated ; *c*, a flower separated, displaying the two paleæ, 3 stamens, and 2 styles.

339. In the grasses the bracts subsist under the general name of chaff. The bracts situated at the base of a spikelet of flowers, are called the glumes, corresponding to the involucre. Those situated at the base of each separate flower are *paleæ*, answering to the calyx or corolla. The pieces of which each *calyx* is composed (generally two) are called valves or pales.

340. Other examples of the involucre are seen in the cup of the acorn, the burr of the chestnut, beech, etc.

341. The forms of inflorescence are exceedingly various, but may all be referred to two classes, as already indicated; the *axillary*, in which all the flowers arise from axillary buds, the *terminal*, in which all the flower-buds are terminal.

342. Axillary inflorescence is called *indefinite*, because the axis, being terminated by a leaf-bud, continues to grow on indefinitely, developing bracts with their axillary flowers as it grows. It is also called *centripetal*, because in the order of time the blossoming commences with the circumference, and proceeds towards the centre in case of a level topped cluster, as the hawthorn, or with the base, and proceeds towards the summit in case of the lengthened cluster, as the mustard.

The student will readily perceive that the *circumference* of a depressed (flattened) inflorescence corresponds to the base of a lengthened one; and also that the *centre* of the former answers to the *summit* of the latter. For when the axis or rachis is lengthened, it is the *centre* which bears it along with it at its apex, leaving the circumference at the base.

343. Terminal inflorescence, on the other hand, is *definite*, implying that the growth of the axis as well as of each branch is definitely arrested and cut short by a flower. It is also *centrifugal*, because the

blossoming commences with the central flower and proceeds in order to the circumference, as in the sweet-william, elder, hydrangea.

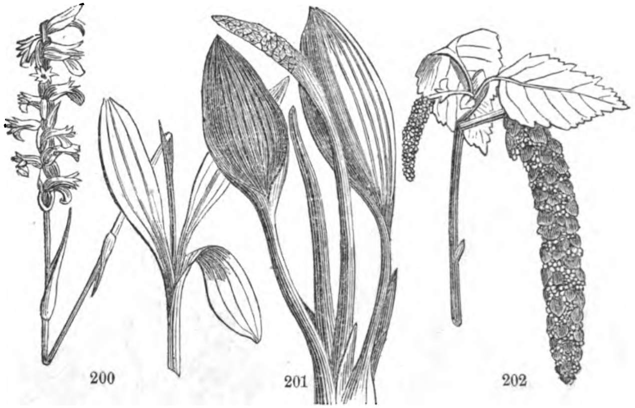
In this kind of inflorescence *all* the flowers are considered terminal because they do in fact (except the first which terminates the axis) terminate *lateral branches* successively produced on a definite plan at the node next below the primary flower.

344. BOTH KINDS OF INFLORESCENCE ARE OCCASIONALLY COMBINED in the same plant, where the *general* system may be distinguished from the *partial* clusters which compose it. Thus in the Compositæ, while the florets of each head open centripetally, the general inflorescence is centrifugal, that is, the terminal head is developed before the lateral ones. But in the Labiatæ the partial clusters (verticillasters) open centrifugally while the general inflorescence is indefinite, proceeding from the base upwards.

345. OF CENTRIPETAL OR AXILLARY INFLORESCENCE THE PRINCIPAL VARIETIES ARE the spike, spadix, catkin, raceme, corymb, umbel, panicle, thyrse, head.

346. THE SPIKE is a long rachis with sessile flowers either scattered, clustered, or crowded upon it, as plantain, mullein, vervain. The so-called spikes of the grasses, as wheat, timothy, are in fact *compound spikes*, bearing little spikes or *spikelets* in place of single flowers.

347. THE SPADIX is a thick, fleshy rachis with flowers closely sessile or imbedded on it, and usually with a spathe, as in the Arum, or without it, as in the Typha.

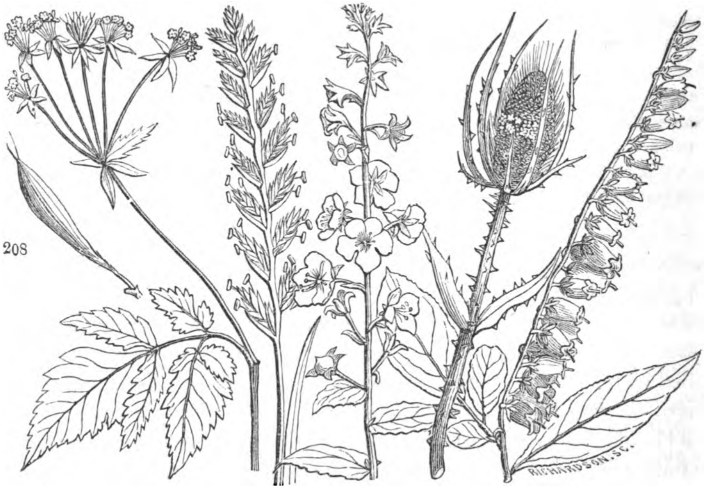


200, Spiranthes cernua; flowers in a twisted spike. 201, Orontium aquaticum; flowers on a naked spadix. 202, Betula lenta; flowers in aments.

348. THE CATKIN OR AMENTUM is a slender, pendant rachis with scaly bracts subtending the naked, sessile flowers, and usually caducous, as in birch, beech, oak, willow.

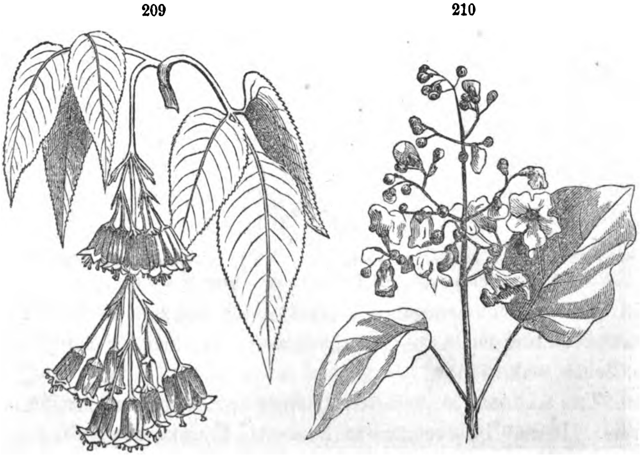
349. THE RACEME is a rachis bearing its flowers on distinct, simple pedicels. It may be erect, as in hyacinth, Pyrola, or pendulous, as in currant, blackberry.

350. **The corymb** differs from the raceme in having the lower pedicels lengthened so as to elevate all the flowers to about the same level, as in the wild thorn.



203, Andromeda racemosa; flowers in a secund raceme. 204, Verbascum Blattaria; raceme. 205, Lolium perenne; a compound spike or a spike of spikelets. 206, Dipsacus sylvestris; head with an involucre of leaves. 207, Osmorhiza longistylis; a compound umbel. 208, Its fruit.

351. **An umbel** consists of several pedicels of about equal length radiating from the same point, the top of the common peduncle, as milk-weed, ginseng, onion. When the pedicels of an umbel become



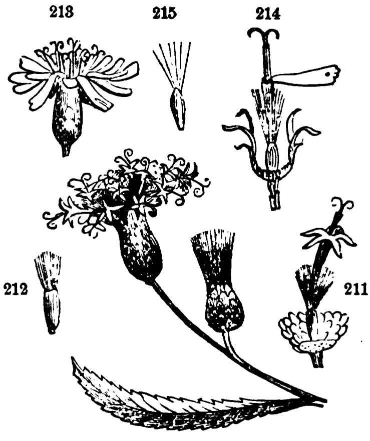
209, Staphylea trifolia; a pendulous, paniculate cyme. 210, Catalpa; a panicle.

themselves umbels, as in caraway and most of the Umbeliferæ, a *compound umbel* is produced. Such secondary umbels are called *umbellets* and the primary pedicels, *rays*.

352. THE PANICLE is a compound inflorescence formed by the irregular branching of the pedicels of the raceme, as in oats, spear-grass, Catalpa.

353. A THYRSE is a sort of compact, oblong, or pyramidal panicle, as in lilac, grape.

354. A HEAD OR CAPITULUM is a sort of reduced umbel, having the flowers all sessile upon the top of the peduncle, as in the button snake-root, button-bush, clover.

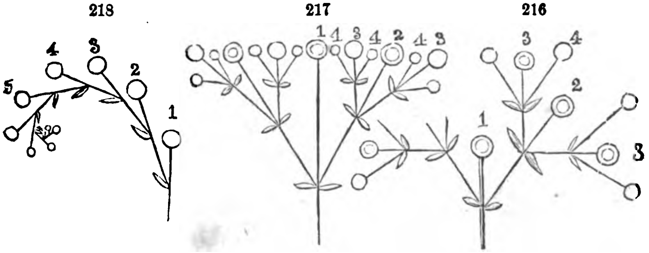


Vernonia fasciculata; flowers in a discoid head with an imbricated involucre. 211, A single flower remaining on the receptacle. 212, A fruit crowned with the pappus. 213, Mulgedium; a head. 214, A single flower remaining on the receptacle. 215, A fruit with pappus.

But the more common examples of the capitulum are seen in the Compositæ, where the summit of the peduncle, that is, the receptacle, is dilated, bearing the sessile flowers above, and scale-like bracts around, as an involucre.

355. THE CAPITULUM OF THE COMPOSITÆ is often called a *compound flower* from its resemblance, the involucre answering to a calyx, the *rays* to the corolla. The flowers are called *florets*, those of the outer circle, *florets of the ray*, generally differing in form from those of the central portions, the *florets of the disk*.

356. OF TERMINAL INFLORESCENCE THE FOLLOWING VARIETIES are described: cyme, fascicle (verticilaster), glomeruli.

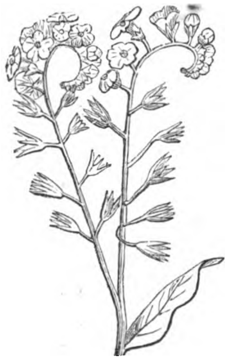


Diagrams; 216 of a cyme; flowers numbered in the order of their development. 217, Cyme fastigiate. 218, Cyme half developed—a scorpoid raceme.

357. CYME is a general term denoting any inflorescence with centri-

fugal evolutions, but is properly applied to that level-topped or fastigiate form which resembles the corymb, as in the elder. If it is loosely spreading, not fastigiate, it is called a *cymose panicle*, as in the chickweed, spergula, etc. If it be rounded, as in the snowball, it is a *globous cyme.*

220



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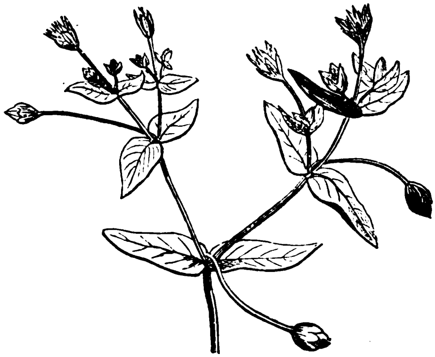
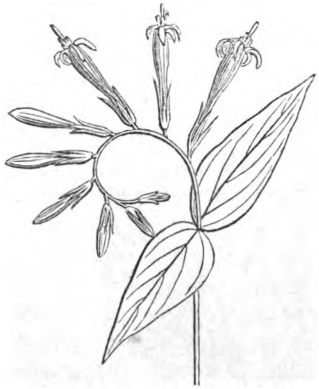


220, Myosotis palustris; scorpoid racemes. 219, Stellaria media; a regular cyme.

358. A SCORPOID CYME, as seen in the sundew, Sedum, and borrage family, is a kind of coiled raceme, unrolling as it blossoms. It is understood to be a half-developed cyme, as illustrated in the cut.

221



221, Spigelia Marilandica; a scorpoid raceme.

359. THE PECULIAR EVOLUTION OF THE CYME is well illustrated in the chick-weed (Alsine media). The first opening flower terminates the axis and stops its growth. Then from the pair of axils next below issue *two* opposite branches, each bearing a pair of leaves and a terminal flower. Next, the same process is repeated with each of these two branches, and so on indefinitely. Thus the stem becomes repeatedly forked, each fork having an older flower in its angle.

360. EVOLUTION OF THE SCORPOID RACEME. But let only *one* branch be developed at the node next below the flower, and that always on the same side, and we have a scorpoid raceme or cyme. Other irregularities occasioned by partial development may also variously disguise the cyme.

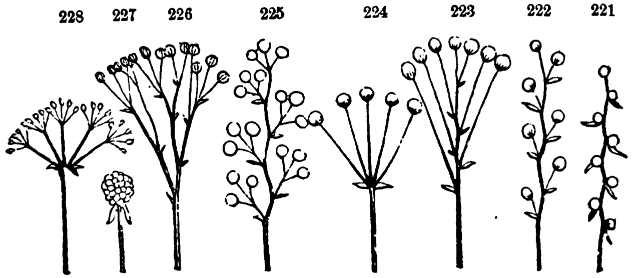
361. FASCICLE. This is a modification of the cyme, with crowded and nearly sessile flowers, as in sweet-william (Dianthus).

362. GLOMERULE, an axillary tufted cluster, with a centrifugal evolution, frequent in the Labiatæ, etc. When they occur in the axils of

opposite leaves and meet around the stem, each pair constitutes a verticilaster or verticil, as in catmint, hoarhound.

363. How THESE MODES ARE MUTUALLY RELATED. All the forms of inflorescence above described may, after all, be shown to be but modifications of a single type, as follows:

Let us commence with the spike, a slender rachis with sessile flowers. Conceive that pedicels be developed for the flowers, — a raceme; let the pedicels branch, — a panicle; or let them all be lengthened to the height of the rachis, — a corymb. Now suppress the rachis to a point, making all the pedicels equal, — an umbel. Once more, suppress all the pedicels, — a head. Now, if in each case we suppose the evolutions of the flowers to be reversed, we have a cymose inflorescence. Finally, by a metamorphosis still more remarkable,



Diagrams illustrating the forms of inflorescence; graduated from the spike to the compound umbel, showing how related to each other.

The entire inflorescence is sometimes transformed into attenuated tendrils, as in the grape.

FLOWERING.

364. DEFINITION. In the bud the floral leaves (sepals and petals) infold the floral organs (stamens and pistils) and conceal them from view. Flowering consists of the opening or expansion of these envelops, displaying every organ now perfected in growth and beauty, and ready for the exercise of its function.

365. PERIOD OF FLOWERING. Each species of plant has its own special season for flowering, uniform in the same climate, but varying in different climates according to the general temperature. Hence each month and each day of the month mark the date of flowering for some one or more species, and these facts, when duly observed and recorded in their proper order, constitute the floral calender for that locality.

366. THE FLORAL CALENDAR is an index of climate, and may vary to a considerable degree in different years for the same locality or for different localities in the same year. Such a calendar is prepared by the botanical student when he carefully journalizes his discoveries from day to day throughout the season.

367. Examples. At Savannah the red maple, shad-bush, blood-root, flower in February; in the District of Columbia in March; at Concord, N. H., in April. In New England the witch-hazel flowers in February; Hepatica in April; dogwood in May; elder in June; lilies in July; boneset in August; asters and Solidagos in September and October; and chrysanthemum in November.

368. The floral clock. Each plant has also its definite hours in the day for opening its flowers and for closing them—for waking and sleeping; and a careful record of these facts (as once made by Linnæus) may seem to indicate the hour of the day. Thus,

The morning glory	opens at	(about)	2 A. M.,	and closes	about	10 A. M.
Rutland beauty	"	"	3 "	"	"	11 "
Vegetable oyster	"	"	4 "	"	"	12 "
Poppy	"	"	5 "			
Bitter-sweet	"	"	6 "			
Water-lily	"	"	7 "			
Scarlet pimpernel	"	"	8 "			
Calendula arvensis	"	"	9 "			
Arenaria rubra	"	"	10 "			
Ornithogalum umbellatum	"	"	11 "			
Passiflora cœrulea	"	"	12 M.			
Pyrethrum	"	"	2 P. M.			
Marvel of Peru	"	"	4 "			
Silene noctiflora	"	"	5 "			
Evening primrose	"	"	6 "			
Lychnis vespertina	"	"	7 "			
Cereus grandiflora	"	"	8 "			

369. The colors of flowers constitute one of their chief attractions, and are of special interest to the florist. By various modes of culture he may often change at will those colors, thus producing numerous varieties, as in the tulip and dahlia. But in scientific descriptions the colors are seldom employed as characteristics on account of their variableness.

370. Classification of colors. De Candolle divides the colors of flowers into two series; 1, those having yellow for their type and capable of varying to red and white, but never to blue; 2, those having blue for their type, and capable of varying to red and white, but not to yellow. The first series is called *Xanthic*, the second, the *Cyanic*. Both series commence with green (which is composed of blue and yellow) and end in red, thus:

Green.

Blue-green.	Yellow-green.
Blue.	Yellow.
Blue-violet.	Yellow-orange.
Violet.	Orange.
Violet-red.	Orange-red.

Red.

371. Examples. The tulip was originally yellow. All its numerous varieties are of the xanthic series. So also the rose and Dahlia. Florists have never yet obtained a blue tulip, rose, or dahlia. The geranium varies throughout the cyanic series, and a yellow geranium is unknown. Different species of the same genus may belong to different series, so also different parts of the same flower.

CHAPTER X.

MORPHOLOGY OF THE FLOWER.

372. The flower as the standard of beauty. So it has ever been regarded. Through this attribute, so evidently divine in its origin, it breathes on the heart an influence which is essentially spiritual, always pleasing, elevating, and pure. The benevolent Thought which first conceived of this crowning glory of the vegetable world had evidently in view the education of man's moral nature as well as *the reproduction and permanence of vegetable nature.*

373. The flower in the light of science. The pleasure of the florist in contemplating the flower as merely an object of taste is not diminished when he comes to view it in the light of science. Parts which he before regarded as embellishments only, now assume new value as indispensable agents in fulfilling a great design; every organ takes form according to the sphere of its office, and the beauful flower no longer appears as the possible accident of a chance-world.

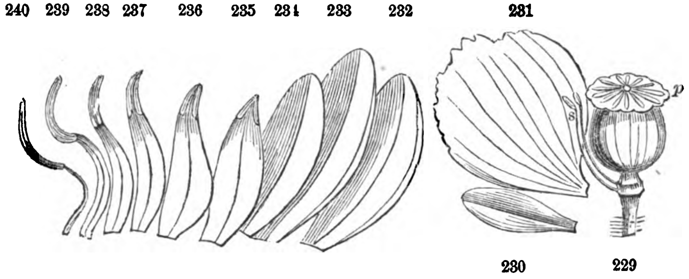
374. Its nature and origin. We have before observed that the flower-bud is, in nature and origin, one and the same with the leaf-bud. Now a leaf-bud is regularly unfolded into a leafy branch. A flower-bud is unfolded into a flower. Hence the flower, in its nature and origin, is one and the same with a leafy branch.

375. Theoretical view. When, therefore, this new necessity arises in the life of a plant, viz., the perpetuation of its species, no new principle or organ is evoked, but *the leaf*, that same protean form which we have already detected in shapes so numerous and diverse, THE LEAF, is yet once more in nature's hand molded into a series of forms of superior elegance, touched with colors more brilliant, and adapted to a higher sphere as *the organs of reproduction.*

376. The evidence on which this theory rests may be referred to two sources; namely, *natural* and *artificial* development. We mention a few instances of each kind, earnestly recommending the student to study for himself the many facts which will fall under his own observation bearing upon this deeply interesting theory.

377. Case of the poppy. The ordinary complete flower, *e. g.*, the poppy, consists of four kinds or sets of organs, viz., the *sepals* (outside), *petals* next, *stamens* and *pistils*, and each kind is quite different and distinct from the others. The metamorphosis of the leaf, first into the sepal then the petal, etc., is so abrupt that it seems to lose its identity at once. But there are some

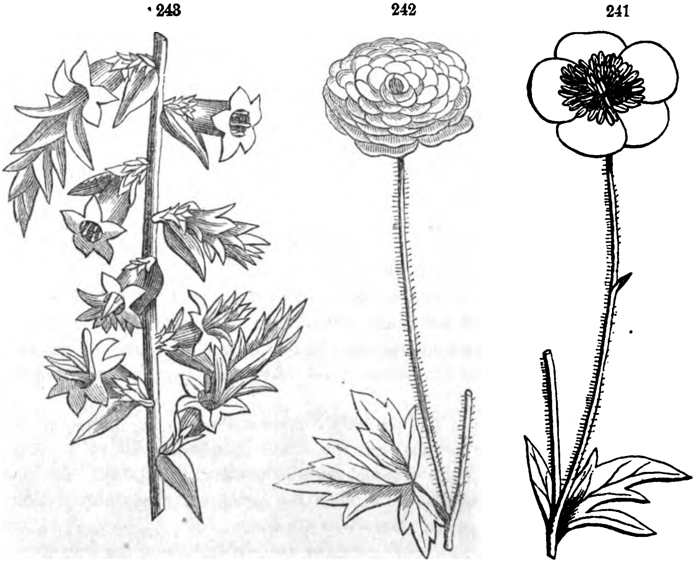
378. Cases in the natural development of plants where the transition of the leaf is gradual, changing insensibly, first to bracts then to sepals, thus apparently making the metamorphosis in question *visible* before our eyes. Such cases



229, Papaver (poppy); *s*, stamens; *p*, stigmas. 230, Sepal. 231, Petal—all very different. 232 Petals of the water-lily (Nymphæa) gradually passing into (240) stamens.

are exactly in point. The leaves of the pæony, large and much divided below, become smaller and more simple above, *gradually* passing into bracts and thence into sepals. In Calycanthus the sepal passes into the petal by gradations so gentle that we can not mark the limit between them. In the lilies these two organs are almost identical. In the water-lily, where the sepal, petal, and stamen are all thus graduated, the transition from petal to stamen is particularly instructive. These two forms meet half way by a perfect series of gradations, when a narrowed petal is capped slightly with the semblance of an anther. And finally, cases of a close resemblance between stamen and pistil, so unlike in the poppy, are not wanting, as in the tulip-tree.

379. FLOWERS ALWAYS REGULAR IN THE EARLY BUD. An early examination of flower-buds often exhibits the several kinds of organs much less diverse than they subsequently become. See the *early* bud of columbine. Those flowers which are



241, Ranunculus acris; a single flower. 242, R. acris, β. plena, a double flower. 243, Epacris impressa; the flowers changing to leafy branches (Lindley).

called *irregular*, as the pea, catmint, violet, are regular, like other flowers, in the early bud; that is, the several petals are at first seen to be precisely similar, becoming dissimilar and distorted in their after growth; so in the stamens and other organs.

380. CASES IN ARTIFICIAL DEVELOPMENT OR TERATOLOGY (*τέρα*, a monstrosity, λόγος), where organs of one kind are converted into those of another kind by cultivation, afford undeniable evidence of the doctrine in question—*the homology of all the floral organs with the leaf.* Such cases are frequent in the garden, and however much admired, they are *monstrous*, because unnatural. In all double flowers, as rose, pæony, Camillia, the stamens have been reconverted into petals, either wholly or partially, some yet remaining in every conceivable stage of the transition. In the double butter-cup (242) the pistils as well as stamens revert to petals, and in the garden cherry, flowering almond, a pair of green leaves occupy the place of the pistils. By still further changes all parts of the flower manifest their foliage affinities, and the entire flower-bud, after having given clear indications of its floral character, is at last developed into a leafy branch. (Fig. 243.)

381. IN CLARKIA, CELASTRUS, damask rose, and other garden plants, cases have been noted wherein the petal asserts its foliar nature by producing a secondary flower-bud in its axil! Thus in a thousand instances of abnormal growth, we find evidence proving the leaf to be the type whence all other forms of appendages are derived, and whither all tend to return.

382. FURTHER EVIDENCE of this view, equally conclusive, is found in the essential agreement of the æstivation of the flower-bud with the phyllotaxy of the branch.

ÆSTIVATION.

383. DEFINITION—IMPORTANCE. This term (from *æstivus*, of summer) refers to the arrangement of the floral envelops while yet in the bud. It is an important subject, since in general the same mode of æstivation regularly characterizes whole tribes or orders. It is to the flower-bud what vernation (*vernus*, spring) is to the leaf-bud.

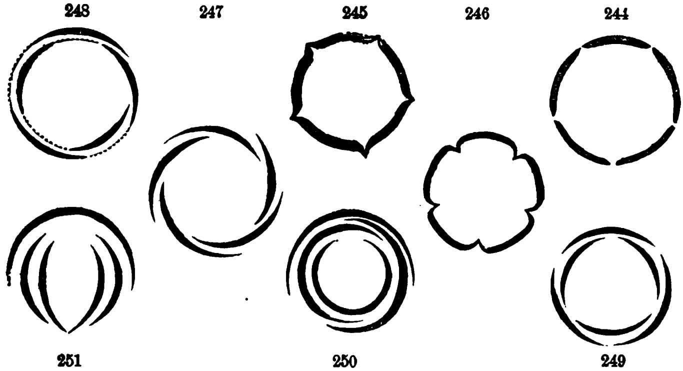
384. THE VARIOUS MODES OF ÆSTIVATION ARE BEST OBSERVED in sections of the bud made by cutting it through horizontally when just ready to open. From such sections our diagrams are copied.

385. SEPARATELY CONSIDERED, we find each organ here folded in ways similar to those of the leaf-bud; that is, the sepal or the petal may be *convolute*, *involute*, *revolute*., etc, terms already defined.

386. COLLECTIVELY CONSIDERED, the æstivation of the flower occurs in four general modes with their variations; the valvate, the contorted, imbricate, and plicate.

387. IN VALVATE ÆSTIVATION the pieces meet by their margins without any overlapping; as in the sepals of the mallow, petals of Hydrangea, valves of a capsule. The following varieties of the valvate occur:

388. INDUPLICATE, where each piece is involute; *i. e.*, has its two margins bent or rolled inwards, as in Clematis; or reduplicate, when each piece is revolute—having its margins bent or rolled outwards, as in the sepals of Althea rosea. (Figs. 245, 246.)



244–251, Modes of æstivation. 250, Petals of the wall-flower.

389. Contorted æstivation, where each piece overlaps its neighbor, all in the same direction, appearing as if twisted together, as in Phlox, flax, oleander. (247, 252.)

390. Imbricated æstivation (*imbrex*, a tile) is a term restricted to those modes in which one or more of the petals or sepals is wholly outside, overlapping two others by both its margins. This kind of æstivation naturally results from the spiral arrangements so common in phyllotaxy, while the valvate and contorted seem identified with the opposite or whorled arrangement. The principal varieties are

252

252, Gossypium herbaceum, the cotton plant. Petals contorted.

391. The quincuntial, consisting of five leaves, two of which are wholly without, two wholly within, and one partly both, or one margin out, the other in, as in the rose family (248). This accompanies the two-thirds plan in phyllotaxy, and corresponds precisely with it, each quincunx being in fact a *cycle* with its internodes suppressed. (§ 232.)

392. The triquetrous, consisting of three leaves in each set, one of which is outside, one inside, and the third partly both, as in tulip, Erythronium, according to the one-third plan in phyllotaxy.

393. **Convolute**, when each leaf wholly involves all that are within it, as do the petals of Magnolia; and *vexillary*, when one piece larger than the rest is folded over them, as in the pea (251).

394. **Plicate** or folded æstivation occurs in tubular or monopetalous flowers, and has many varieties, of which the most remarkable is the *supervolute*, where the projecting folds all turn obliquely in the same direction, as in morning-glory, thorn-apple (Datura).

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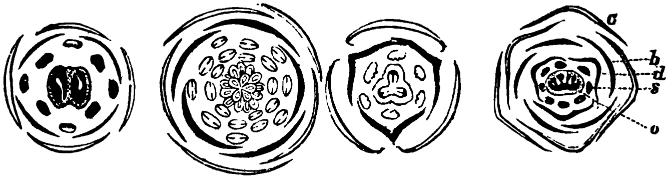

Diagrams of flowers (as seen by cross-sections). 253, Jeffersonia diphylla: *o*, ovary; *s*, stamens; *d*, inner row of petals, æstivation triquetrous; *b*, outer row of petals, æstivation contorted; *c*, sepals, æstivation quincuntial. 254, Lily. 255, Strawberry. 256, Mustard. The pupil will designate the modes of æstivation.

The æstivation of the sepals often differs from that of the petals in the same flower. Thus, in the pink the sepals are imbricated and the petals contorted.

395. **The position on the parts of the flower**, with respect to the main axis and the bract whence it arises, is often important in description. That part which is adjacent to the axis is the *posterior* or upper, while that which looks toward the bract is the *anterior* or lower part.

THE FLORAL ORGANS.

396. **Technical definition of the flower.** The flower is an assemblage of leaves more delicately and variously formed, borne at the upper nodes of the axis where the internodes are undeveloped. This portion of the axis is called

397. **The receptacle or torus.** It is the axis of the flower situated at the summit of the flower-stalk. Its form above is commonly that of a flattened or somewhat conical disk, the center of which corresponds with the apex of the axis.

398. **The flower may consist** of the following members: 1, the *floral envelops*; 2, the *essential floral organs.*

399. **The floral envelops** consist of one or more circles or *whorls* of leaves surrounding the essential organs. The outer of these whorls is called the *calyx* and the other, if there be any, the *corolla.* The calyx may, therefore, exist without the corolla, but the corolla can not exist without

400. **The calyx.** This is a Greek word signifying a cup. It is applied to the external envelop of the flower, consisting of a whorl of

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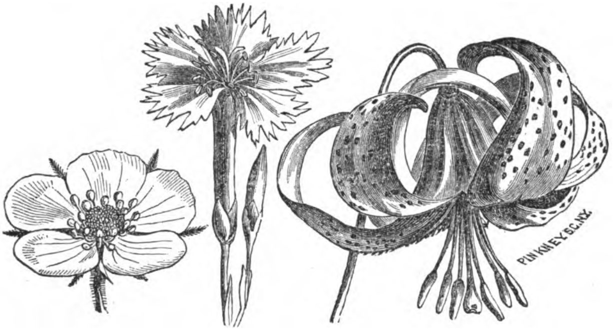

257, Flower of the strawberry. 258, Flower of the pink. 259, Flower of the lily (Lilium superbum). The pupil will point out the parts.

leaves with their edges distinct or united, usually green, but sometimes highly colored. The calyx leaves are called *sepals*.

401. **Corolla** is a Latin word signifying a little crown, applied to the interior envelop of the flower. It consists of one or more circles of leaves, either distinct or united by their edges, usually of some other color than green, and of a more delicate texture than the calyx. Its leaves are called *petals*.

402. **Perianth** (*περί*, around, *ἄνθος*, flower) is a word in common use to designate the floral envelops, *as a whole*, without distinction of calyx and corolla. It is used in description, especially when these two envelops are so similar as not to be readily distinguished, as in the tulip, lily, and the endogens generally; also where only one envelop exists, as in Phytolacca, elm, etc. (259, per.)

403. **The essential floral organs** stand within the circles of the perianth, and are so called because they are the immediate instruments in perfecting the seed and thus accomplishing the final purposes of the flower. These organs are of two kinds, perfectly distinct in position and office; viz., the stamens and the pistils.

404. **The stamens** are those thread-like organs situated just within the perianth and around the pistils. Their number varies from one to a hundred or more; but the most common number is *five*. Collectively they are called the *andrœcium* (*ἄνδρες*,* stamens, *οἶκος*, a house).

405. **The pistils** (called also carpels) occupy the center of the flower at the absolute terminus of the flowering axis. They are sometimes numerous, often apparently but one, always destined to bear the seed. Collectively they are called the *gynœcium* (*γυνή*, pistil, *οἶκος*).

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* The plural of *ανῆρ*, a man, a term applied to the stamen by Linnæus in accordance with his favorite theory of the sexes of plants. The term *γυνη*, woman, is, on the same ground, applied to the pistil.

406. Recapitulation. Thus we have noticed the members of the flower in the order of their succession from the outer to the inner circle. Now, in regard to the receptacle on which they stand in concentric whorls, we find (reversing the order) the gynœcium in the midst, the center of the flower, the andrœcium encircling it, the corolla next without, and the calyx embracing the whole.

407. Appendages. These are the four proper members or sets of organs composing the flower. Occasionally we meet with a fifth between the corolla and stamens, not easily referrible to either, like the *scales* in the throat of the Borrageworts, or the *crown* of the Narcissus and jonquils. Such are regarded as appendages, not necessary to the completeness of the flower.

THE PLAN OF THE FLOWER.

408. Essential unity combined with endless diversity is every where *a characteristic of nature.* Herein consists the perpetual charm of her presence and the perpetual reward of her diligent study. There is no better example of this happy combination than is found in the structure of the flower. Unity or uniformity, when often repeated, becomes monotony. Diversity without unity is confusion. Hence, in our study of the thousand forms in which God has attired the flower we shall arrive at no satisfactory result until we come to discern that unity of plan, that *simple idea* of the flower in which all its diversities harmonize. *There is such an idea.* It originated in the Infinite Mind. Let us search for it.

409. The floral organs. We have already seen that the flower may consist of four sets of organs—calyx, corolla, andrœcium, gynœcium; or of four *kinds* of organs—sepals, petals, stamens, pistils, each arranged circularly around a common center.

410. Symmetry of the flower. Now as the leaves of a branch are definitely apportioned into equal cycles, we naturally look for a corresponding *symmetry* in the flower. Each set of organs should consist of at least one cycle. And as the cycle itself may vary numerically, being 2-leaved, 3-leaved, 5-leaved, etc., in different species, so in the flower each cycle or set may be 2-parted, 3-parted, 5-parted, etc. That is, the sepals, petals, stamens, pistils, may each be two in number, or three, or four, or five in number, etc.

411. Again, in relative position the organs of each set, as a rule, alternate with the organs of each adjacent set; the petals alternate with the sepals and stamens, the stamens with the petals and pistils. This alternation accords with the opposite and verticillate arrangement of leaves, where (§ 226) the leaves of any given circle do not stand exactly over the leaves of the next circle below, but over the intervals between them. In a word,

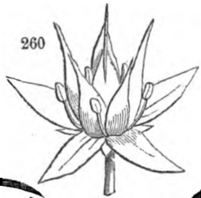
412. The typical flower, one that exemplifies the full idea of the floral structure, consists of four different circles of organs, each circle having the same number of separate, alternating parts. Such a flower is not only

Perfect, having both the essential organs, but also
Complete, having the four kinds of organs.

Regular, the organs of the same kind similar, and
Symmetrical, the same number of organs in each whorl.

413. SELDOM REALIZED. Happily, this our conception of the typical flower is not often realized in nature, although the tendency toward it is universal. Deviations occur in every imaginable mode and degree, causing that endless variety in the floral world which we never cease to admire.

414. EXAMPLES. In our cut (Pink, 258) illustrating the organization of the flower the tendency in this direction is evident, but the stamens are too many and the pistils seem too few. Among the Flaxworts and the Houseleek tribe, however, are some good examples. The flower of the flax combines very nearly all the conditions above specified. It is complete, regular, symmetrical. Its organs are alternate and all separate, and (disregarding the slight cohesion of the pistils at their base) this flower well realizes our type. But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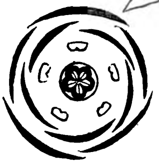
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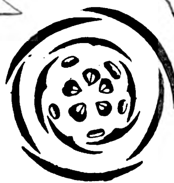
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260, *bis*, Flower of Crassula lactea, regular, symmetrical, organs distinct. 261, Diagram showing its plan. 262, Flower of the Scarlet Flax. 263, Diagram of its plan.

415. THE FLOWERS OF CRASSULA, an African genus sometimes cultivated, afford unexceptionable examples, the sepals, petals, stamens, and pistils each being five in number, regularly alternating and perfectly separate.

416. FLOWERS OF SEDUM. Admitting two whorls of stamens instead of one, we have a good example of our type in stone-crop (Sedum ternatum), a little fleshy herb of our woods. Its flowers are both 4-parted and 5-parted in the same plant. See also the 12-parted flowers of the common houseleek.

417. HOW TO STUDY THE FLOWER. If, with this type as our adopted standard of the floral structure, we compare any of the myriads of different forms which occur, we shall be able to trace out the features of the general plan even among the widest deviations. The more important of them are included in the following synopsis:—

1. Variations in the radical number of the flower.
2. Deficiencies rendering the flower
    a, Incomplete,
    b, Imperfect,
    c, Unsymmetrical,
    d, Organs opposite.

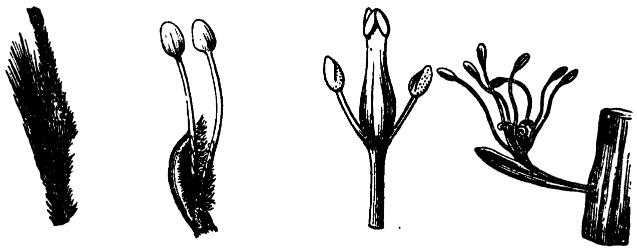
3. Redundancies,
    a, In the multiplication of organs,
    b, In appendicular organs.
4. Union of parts.
    a, By cohesions,
    b, By adhesions.
5. Irregularities of development,
    a, In homogenous parts,
    b, In the receptacle.
6. Combined deviations.

We shall consider these several topics in their order.

418. THE RADICAL NUMBER OF THE FLOWER is that which enumerates the parts composing each whorl. It varies from one to twenty, and is expressed thus: $\sqrt{}$, $\sqrt[3]{}$, $\sqrt[4]{}$, $\sqrt[5]{}$, etc., which mathematical expressions are to be read by the words, disnerous (δις, two, μέρος, part), or 2-parted; trimerous, or 3-parted; 4-merous, or 4-parted; pentamerous, or 5-parted; 6-merous, or 6-parted, etc.

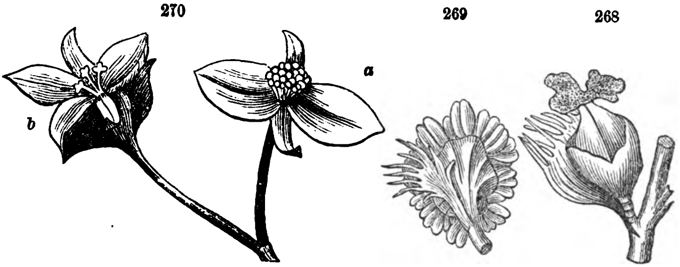
419. EXOGENS AND ENDOGENS DISTINGUISHED. Pentamerous ($\sqrt[5]{}$) flowers, like the rose, flax, when each whorl is (naturally) 5-parted, are more generally characteristic of the exogenous plants, $\sqrt[3]{}$ flowers of the endogens, as the lily, Trillium. The flowers of Fuchsia are $\sqrt[4]{}$, of Circæa $\sqrt{}$, and of Hippuris 1 $\sqrt{}$.

420. DEFICIENCIES. Incomplete flowers often occur. They lack some one or more entire sets of organs. When only one of the floral envelops, the calyx, exists, the flower is said to be *apetalous* or *monochamydeous* (χλαμὺς, a cloak), as in elm, Phytolacca. These terms are also loosely applied to such plants as rhubarb, Anemone, liverwort, where the pieces of the perianth are all similar, although in two or three whorls. When the perianth is wholly wanting, the flower is said to be *achlamydeous* or *naked*, as in lizard-tail. (264.)



264, Flower of Saururus (lizard-tail); achlymydeous. 265, Flower of Fraxinus (ash). 266, Flower of Salix (willow), staminate. 267, pistillate.

421. IMPERFECT FLOWERS are also of frequent occurrence. They are deficient in respect to the essential organs. A *sterile* or staminate flower (denoted thus ♂) has stamens without pistils. A *fertile* or pistillate flower (♀) has pistils without stamens. Such flowers being counterparts of each other, and *both* necessary to the perfection of the seed, must exist either together upon the same plant or upon separate plants of the same species. In the former case the species is monœcious (⚥) as in oak; in the latter case diœcious (♂ ♀) as in willow. The term *diclinous*, denoting either ⚥ or ♂ ♀ without distinction, is in common use.



268, Pistillate flower of Balm-of-Gilead. 269, Staminate. 270, Diploclinium Evansianum. *a*, staminate; *b*, pistillate.

422. A NEUTRAL FLOWER is a perianth or calyx only, having neither stamens nor pistils. Such are the ray-flowers of many of the Compositæ, and of the cymes of Hydrangea, high cranberry, etc., which in cultivation may all become neutral, as in the snow-ball.

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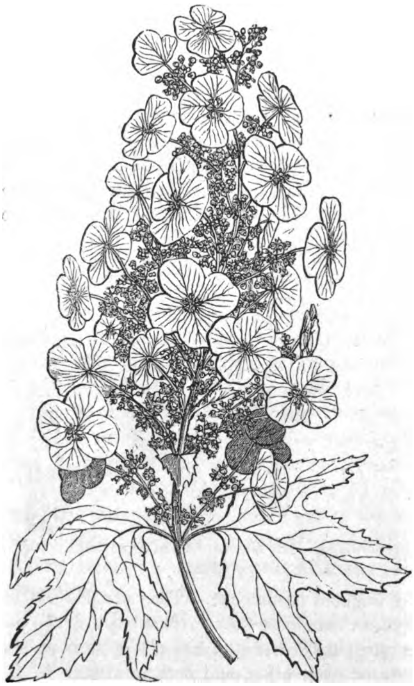


271, "Radiant" panicle of Hydrangea quercifolium; the larger flowers neutral.

423. UNSYMMETRICAL FLOWERS. The term symmetry, as used in botany, refers to number only. A flower becomes unsymmetrical by the partial development of any set or circle in respect to the number of its organs. The mustard family affords a good example.

424. FLOWERS OF THE CRUCIFERS. The flowers of mustard, cress, etc., are understood to be 4-merous ($\sqrt[4]{}$). The sepals are four, petals four, but the stamens are six and the styles but two. The stamens are arranged in two circles, having two of those in the outer circle suppressed or reduced to mere glands. Two of the carpels are also suppressed. (256.)

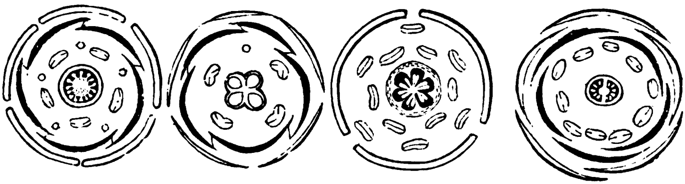
425. IN THE MINT FAMILY and the figworts one or three of the stamens is generally abortive. Here, while the flowers are $\sqrt[5]{}$, the stamens are four in some species and only two in others. The missing stamens, however, often appear in the guise of slender processes—the rudiments of stamens—proving in an interesting manner the natural tendency to symmetry.

426. OTHER EXAMPLES. In the $\sqrt[4]{}$ flowers of poppy, the sepals are but two; in $\sqrt[5]{}$ spring-beauty they are but two; in both cases too few for symmetry. In lark-

spur the $\sqrt[5]{}$ flowers have but four petals, and in monk's-hood, also $\sqrt[5]{}$, the petals are apparently but two strangely deformed bodies. A careful inspection, however, generally reveals the other three, very minute, in their proper places, as displayed in the cut. (283.)

427. "ORGANS OPPOSITE" is a condition much less frequent than "organs alternate," but is highly interesting, as being sometimes characteristic of whole families. Thus in the primrose, thrift, and buckthorn families, the stamens always stand opposite to the petals!

428. HOW HAPPENS THIS? Among the primworts this question is solved in the flowers of Lysimachia and Samolus, where we find a circle of five teeth (abortive filaments) between the petals and stamens, alternating with both sets, thus restoring the lost symmetry. Hence we infer that in such cases generally a circle of alternating organs has been either partially or wholly suppressed. In the buckthorn, however, a different explanation has been given.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Diagrams. 272, Flower of Samolus, showing the rudimentary stamens alternating with the perfect. 273, Flower of a Labiate plant, showing the place of the deficient stamen. 274, Flower of Asarum; three sepals, twelve stamens, etc. 275, Flower of Saxifrage; two pistils, ten stamens, etc.

429. THE MULTIPLICATION OF ORGANS is exceedingly common, and usually according to a definite plan. The increase takes place, as a rule, by circles, and consequently by *multiples*. That is, *e. g.*, the stamens of a $\sqrt[3]{}$ flower, if increased, will be so by 3s; of a $\sqrt[5]{}$ flower by 5s, etc., sometimes to the extent of twenty such circles.

430. CROWFOOTS AND ROSEWORTS. In the crowfoot family the stamens are almost always multiplied. The carpels are also generally multiplied, yet often, on the contrary, diminished, as in the pæony. In Rosaceæ, also, the stamens are generally multiplied, while the carpels exist in all conditions as to number. Thus in strawberry they are multiplied, in the apple they are regularly five, in agrimony reduced to two, and in the cherry to one.

431. OTHER CASES. In Magnolia the $\sqrt[3]{}$ flowers have three sepals in one circle, six or nine petals in two or three circles, numerous stamens and carpels in many circles of each. In the $\sqrt[4]{}$ flowers or blood-root there are two sepals, eight petals, twenty-four stamens, and two carpels.

432. INCREMENT BY CLUSTERS (CHORISIS). In other cases the organs seem to be increased in number by clusters rather than by circles, as when in the same circle several stamens stand in the place of one, *e. g.*, in squirrel-corn, st. johnswort, linden. Such cases afford wide scope for conjecture. Perhaps each cluster originates by division, as the compound from the simple leaf; or as a tuft of axillary leaves; or thirdly, by a partial union of organs.

433. APPENDICULAR ORGANS (§ 407) consist of spurs, scales, crown, glands, etc., and often afford excellent distinctive marks. The old term

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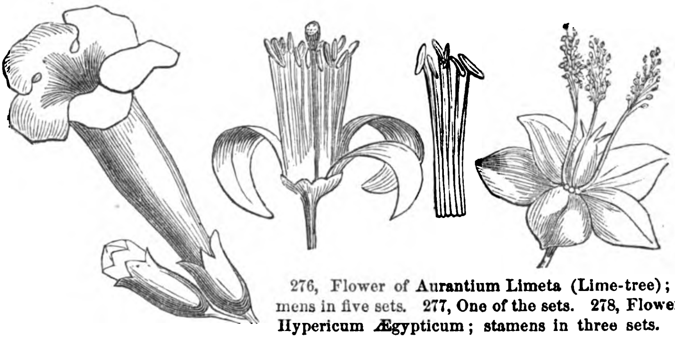

276, Flower of **Aurantium Limeta (Lime-tree)**; stamens in five sets. 277, One of the sets. 278, Flower of Hypericum Ægypticum; stamens in three sets. 279, Flower of Tecoma radicans; petals cohering into a tube, free only at top. Sepals also coherent.

nectary was indiscriminately applied to all such organs, because some of them produced honey.

434. SPURS are singular processes of the flower, tubular and projecting from behind it. In columbine each petal is thus spurred; in violet, one petal only. In larkspur, a petal and a sepal, the spur of the latter inclosing that of the former. The curved spur of the jewel-weed belongs to a sepal. (280, 281.)

435. SCALES are attached to the inner side of the corolla, usually upon the claw of the petals, as in butter-cups, or within the throat of the corolla tube, as in the Borrageworts. Similar appendages, when enlarged and conspicuous, constitute a *crown* in catchfly, corn-cockle The flowers of Narcissus are distinguished by an excessively large crown or *corona*, with its parts all blended into a tube or rim.

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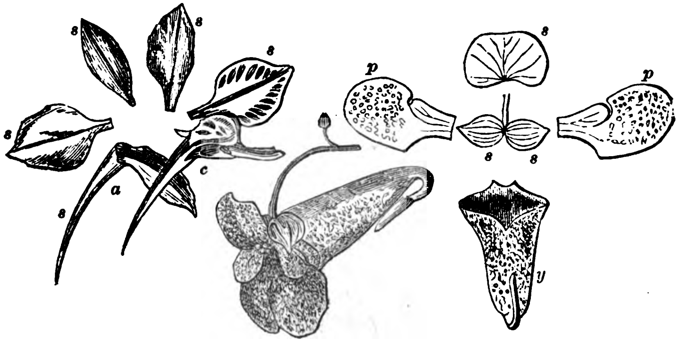

Flower of Delphinium Consolida (common larkspur), displaying, *s, s, s, s, s*, the five sepals, *a*, the upper one spurred; *c*, the corolla of four petals here united into one and produced into a spur. 281, Flower of Impatiens fulva (touch-me-not). 282, Displaying, *S, s, s, y*, the four sepals, *S*, the anterior one, being probably double, and *y*, saccate and spurred; *p, p*, the two petals, both double.

436. **Glandular bodies** are often found upon the receptable in the places of missing stamens or carpels, or as abortive organs of some kind. Examples are seen in the Crucifers and grape. In grass-Parnassus they are stalked and resemble stamens.

437. **Union of organs.** This condition in some way occurs in almost every flower, and more perhaps than any other cause tends to disguise its plan and origin. The separate pieces which stood each as the representative of a leaf, now, by a gradual fusion, lose themselves in the common mass. Nevertheless, marks of this process are always discernible either in parts yet remaining *free*, or in the *seams* where the edges were conjoined. The floral organs may unite by *cohesion* or *adhesion*.

438. **Cohesion**, when the parts of the same whorl are joined together, as the sepals of the pink, the petals of morning-glory, the stamens of mallows, the carpels of poppy.

439. **Adhesion**, when the parts of different whorls are conjoined, as the stamens with the corolla in phlox, with the pistils in milkweed, ladies' slipper; or calyx with ovary in apple or wintergreen (Gaultheria).

440. **The adjective free** is used in a sense opposite to adhesion, implying that the organ is inserted on (or grows out of) the receptacle, and otherwise separated from any other kind of organ. The adjective *distinct* is opposed to cohesion, implying that like organs are separate from each other.

This subject and also the next will be more particularly noticed in another chapter.

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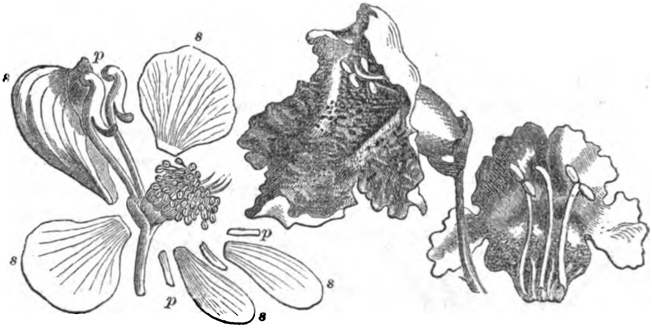

283, Flower of Aconitum Napellus displayed; *s*, *s*, *s*, *s*, *s*, the five sepals, the upper one hooded; *p*, *p*, *p*, the five petals, of which the two upper are nectaries covered by the hood, and the three lower very minute. 284, Flower of Catalpa, 2-lipped, 5-lobed. 285, Corolla laid open, showing the two perfect stamens and the three rudimentary.

441. **Irregular development.** Our typical flower, it will be remembered, is regular; and observation proves that all flowers are actually alike regular in the early bud. These inequalities or "one-sided" forms, therefore, which characterize certain flowers are occasioned by subsequent irregular growth from a regular type. The irregularity of flowers may consist

1. In the unequal *size* of like organs (petals of mullein).
2. In their dissimilar *forms* or *positions* (petals of the pea).
3. In the unequal *cohesion* of like parts (petals of Lobelia).
4. In unequal *suppressions* (stamens of the Labiate flowers, where, indeed, as in many other flowers, all these phases of irregularity are combined).

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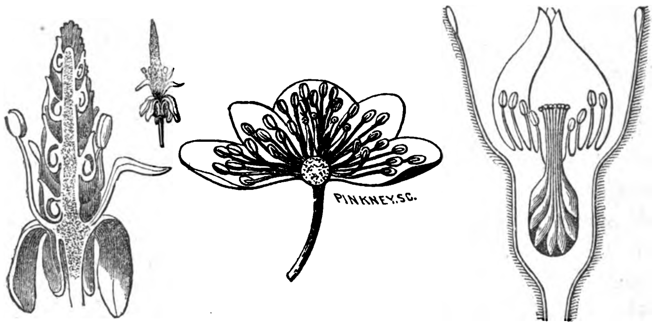

286, Flower (magnified) of Myosurus; a vertical section showing its elongated receptacle, etc. 287, The same, natural size. 288, Flower of Isopyrum biternatum; vertical section, showing the convex or globular receptacle, etc. 289, Flower of rose, showing its excavated torus.

442. THE REGULAR RECEPTACLE has no internodes. It bears the several whorls of the flower in close contact with each other, and is usually short and depressed.

443. LENGTHENED RECEPTACLE. When these whorls are numerous, as in buttercups, tulip-tree, the receptacle is necessarily elongated. So in Myosurus, blackberry, strawberry. In the two latter it imbibes the nutritious juices of the plant and becomes a part of the fruit.

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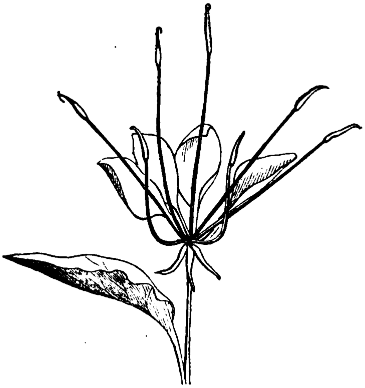

290, Flower of Cleome pungens, showing its ovary, *o*, mounted on a long stype.

444. EXCAVATED RECEPTACLE. On the contrary, the torus instead of lengthening may be hollowed out in the center. The carpels of the rose are situated in such a cavity, while the other organs are borne upou its elevated rim. In Nelumbium the carpels are immersed in as many separate excavations in a large, fleshy receptacle.

445. BUT THE INTERNODES OF THE TORUS ARE SOMETIMES DEVELOPED, *e. g.*, in noble liverwort a short internode between the corolla and calyx

has changed the latter (technically) to an involucre. In the pink a similar internode renders the ovary *stipitate*. In the Caper family the torus is developed into long internodes, sometimes raising the ovary upon a long stipe, sometimes the stamens and ovary.

446. **The disk** is a portion of the receptacle raised into a rim somewhere in the midst of the whorls. It is found between the ovary and stamens in pæony and buckthorn. It bears the stamens in maple, mignionette, and crowns the ovary in the Umbelliferæ. Finally

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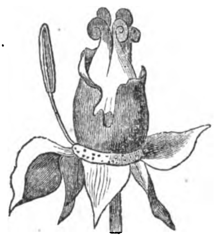

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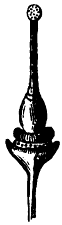

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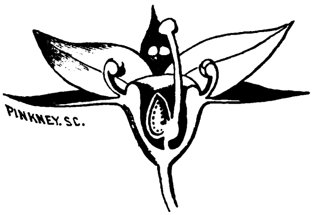


291, Pæonia Montan, showing its very large disk (*d*) sheathing the ovaries (*p*). 292, Pistil of the lemon, with its base surrounded by the disk, *d*. 293, Section of flower of Alchemilla, showing its single simple pistil, large disk, etc.

447. **Combined deviations** are quite frequent, and sometimes obscure the typical character of the flower to such a degree as to require close observation in tracing it out. The study of such cases is full of both amusement and improvement.

448. **For example**, the $\sqrt[4]{}$ poppy has suppression in the calyx, multiplication in the stamens and carpels, and in the latter cohesion also. The $\sqrt[5]{}$ sage has cohesion and irregularity in the calyx, every kind of irregularity in the corolla, suppression and irregularity in the stamens, suppression and cohesion in the pistils. The $\sqrt[3]{}$ Cypripedium is perfectly symmetrical, yet has irregular cohesion in the calyx, great inequality in the petals, cohesion, adhesion, and metamorphosis in the stamens, and cohesion in the carpels.

(In this way let the pupil analyze the deviations in the flower of Geranium, hollyhock, moth mullein, larkspur, sweetbriar, touch-me-not, Petunia, snapdragon, violet, Polygala, squirrel-corn, Orchis, henbit, monk's-hood, Calceolaria, etc.)

CHAPTER XI.

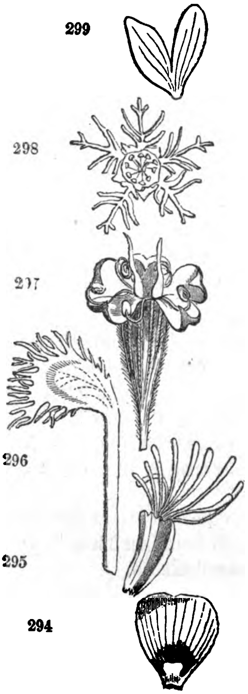
THE FLORAL ENVELOPS, OR PERIANTH.

449. **Idea of the typical flower.** In our idea of the typical flower, the perianth consists of two whorls of expanded floral leaves encircling and protecting the more delicate essential organs in their midst. The outer circle, calyx, is ordinarily green and far less conspicuous than the inner circle of highly colored leaves—the corolla.

450. Exceptions. But to this, as to all other general rules, there are many exceptions. Strictly speaking, the calyx and corolla are in no way distinguishable except by *position*. The *outer* circle is the calyx, whatever be its form or color, and the *inner*, if there be more than one, is the corolla.

451. Rules. The *sepals* of the calyx and *petals* of the corolla are, according to rule, equal in number and severally disconnected save by the torus on which they stand.

452. Resemblances. The sepals more nearly resemble true leaves in texture and color; but the petals in form. Both have veins and retain more or less the same venation which characterizes the grand division to which the plant belongs (§ 258).



Forms of petals. 294, Buttercup, showing the scale at base. 295. Mignonette, fringed at top. 296, Silene stellata, fringed and unguiculate. 297, Flower of Osmorhiza longistylis, petals inflected. 298, Flower of Mitella diphylla, petals pectinate-pinnatifid. 299, Petal of Cerastium nutans, 2-cleft.

453. Parts. Both blade and petiole are distinguishable in the floral leaves, especially in the petals. The blade or expanded part is here called *limb* or *lamina*: the petiolar part, when narrowed into a stalk, is called the *claw*.

454. Nature of the sepals. The sepals are more generally sessile, like bud-scales, and appear to represent the leaf-stalk only, with margins dilated like a sheathing petiole. In confirmation of this view, we find in some flowers, as the pæony and rose, the lamina also developed, but smaller than the petiolar part.

455. Forms of petals. In form or outline there is a general resemblance between the limb and the leaf. It is ovate, oval, lanceolate, obcordate, orbicular, etc. In margin it is generally entire. Some peculiar forms, however, should be noticed, as the bilobate petal of the chickweed, the pinnatifid petal of miterwort, the inflected petal of the Umbeliferæ, the fan-shaped petal of pink, the fringed (fimbriate) petal of campion (silene stellata), the hooded sepal of Napellus, the saccate petal of Calceolaria, Cypripedium.

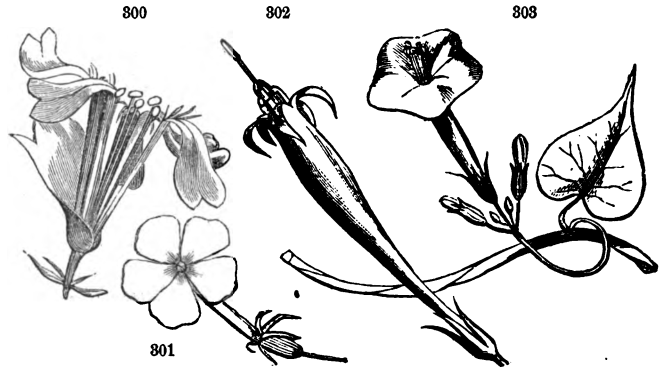
456. Nectary. The limb is, moreover, often distorted into a true nectary, spurred, as already shown (§ 434), or otherwise deformed, as in Napellus, Coptis, etc.

457. Union. We have seen that the floral organs are often in various ways united. Considering their crowded state in the flower, we rather wonder that they do not always coalesce in their growth.

458. The calyx with united sepals was called by the early botanists *monosepalous ;* the corolla with united petals was called *monopetalous* (*μόνος*, one—from the false idea that such an organ consisted of a single piece or leaf!). Opposed to these terms were *polypetalous* (*πολύς*, many), petals distinct, and *polysepalous*, sepals distinct.

459. The monosepalous calyx, or monopetalous corolla, although thus compounded of several pieces, is usually described as a simple organ, wheel-shaped, cup-shaped, tubular, according to the degree of cohesion. The lower part of it, formed by the united claws, whether long or short, is the *tube ;* the upper part, composed of the confluent laminæ, is the *border* or *limb ;* the opening of the tube above is the throat.

460. The border is either lobed, toothed, crenate, etc., by the distinct ends of the pieces composing it, as in the calyx of pink, the calyx and corolla of Primula, Phlox, and bellwort, or it may become by a complete lateral cohesion, *entire*, as in morning-glory. Here the compound nature of the organ is shown by the *seams* alone.

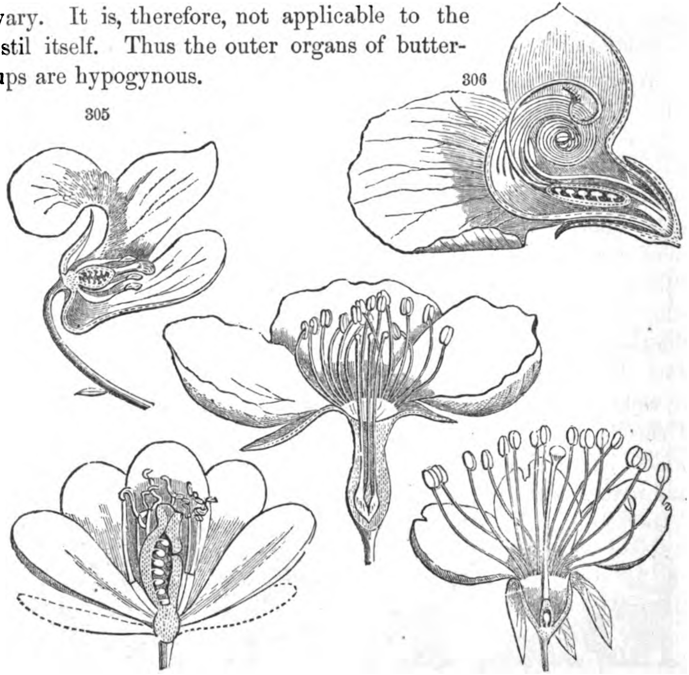


300, Flower of Saponaria (bouncing bet) ; petals and claws quite distinct. 301, Phlox ; claws united, with lamina distinct. 302, Spigelia (pink-root), petals still further united. 303, Quamoclit coccinea, petals united throughout.

461. A terminal cohesion, where summit as well as sides are joined forming a *cap* rather than cup, rarely occurs, as in the calyx of the garden Escholtzia and the corolla of the grape.

462. The modes of adhesion are various and important, furnishing some of the most valuable distinctive characters. An organ is said to be *adherent* when it is conjoined with some dissimilar organ, as stamen with pistil. All the organs of our typical flower are described as *free.*

463. Hypogynous (υπώ, under, γυνή, pistil) is an adjective term in frequent use, denoting that the organs are inserted into the receptacle *under* or at the base of the free pistil or ovary. It is, therefore, not applicable to the pistil itself. Thus the outer organs of buttercups are hypogynous.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Section of flowers. 304, Jeffersonia diphylla, hypogynous. 305, Viola rotundifolia. 306 Phaseolus multiflorus (bean, organs spirally twisted). 307, Pyrus (Pear), perigynous; ovaries nearly inclosed. 308, Prunus (plum); ovary not inclosed.

464. Perigynous (περί, around) denotes that the organ is inserted on the calyx-tube *around* the free ovary. Thus in Phlox the stamens are inserted on the tube of the corolla. In cherry both stamens and petals are (apparently) inserted on the calyx-tube. The calyx can never be perigynous.

465. Epigynous (επὶ, upon) denotes that all the organs are apparently inserted upon the ovary, as seen in the apple, caraway, sunflower. The common phrases "calyx superior," "ovary inferior," have the same signification as calyx epigynous, all implying the apparent insertion of the organs upon or above the ovary.

466. There is also another set of terms in use, of the same application, founded upon a more modern view of the floral structure, viz., "calyx adherent," "ovary adherent." Which is the better form of expression will depend upon our location of the receptacle.

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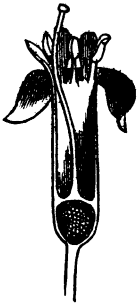

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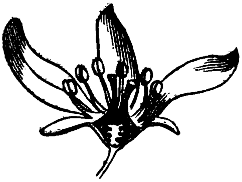

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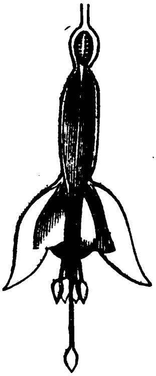

309, Ribes aureum (Missouri Currant); stamens and petals perig.; ovary inferior. 310, Saxifraga Virginiensis; half superior. 311, Fuchsia gracilis (Ear-drop); inferior; stamens *epipetalous*.

467. In the cases above cited, it is commonly taught that the receptacle is located at the base of the ovary, and that all the organs thence arising are adherent to its sides. Another doctrine is also taught, viz., that the receptacle itself may be elevated and become perigynous or epigynous, or, in other words, the ovary may be imbedded in the foot-stalk. That it is so in the rose (289) we can hardly doubt. The so-called calyx-tube of the cherry, peach, is certainly an analogous structure, more expanded, and so is the more contracted "calyx tube" of the apple, pomegranate. The analogy extends throughout the Roseworts, and perhaps still further.

468. Calyx half-superior. Calyx superior or free, ovary inferior or free, are all phrases of the same import as calyx hypogynous. Between the two conditions, calyx superior and calyx inferior, there are numerous gradations, of which one only is defined, to wit, calyx half-superior, as exemplified in the mock orange (and 313).

469. Special forms of the perianth, whether calyx, corolla, or both, have been named and described. We may arrange them thus:—

Polypetalous, *regular*—Cruciform, rosaceous, caryophyllaceous, liliaceous. *Irregular*—papilionaceous.

Monopetalous, *regular* mostly—rotate, cup-shaped, campanulate, urceolate, funnel-form, salver-form, tubular. *Irregular*—ligulate, labiate, orchidaceous.

470. Cruciform (*crux*, a cross) or cross-shaped, implies that four long clawed, spreading petals stand at right angles to each other, as in the flowers of the mustard family (Cruciferæ) in general.

471. Rosaceous, rose-like; a flower with five short-clawed, spreading petals.

472. Caryophyllaceous, pink-like; a five-petaled corolla, with long, erect claws and spreading laminæ.

463. Liliaceous, like the lily; a flower with a six-leaved perianth, each leaf gradually spreading so as to resemble, as a whole, the funnel-form.

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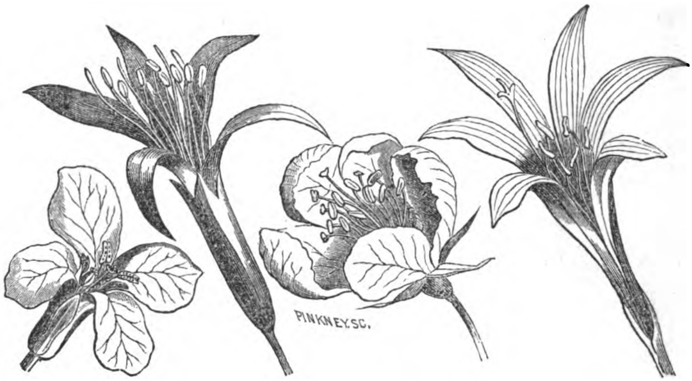
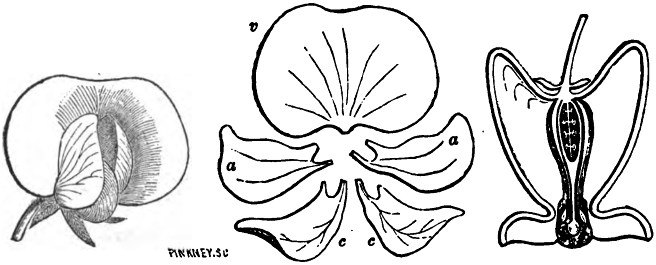


Forms of corollas. 812, Cheiranthus (stock). 813, Silene regia (scarlet catchfly). 814, Pyrus coronaria. 815, Amaryllis (Atamasco lily).

474. Papilionaceous, butterfly-shaped; a corolla consisting of five dissimilar petals, designated thus: the upper, largest, and exterior petal is the banner (*vexillum*); the two lateral, half-exterior, are the wings (*alæ*); the two lower, interior petals, often united at their lower margin, are the keel (*carina*). The flowers of the pea, locust, clover, and of the great family of the Leguminosæ in general are examples.

816 817 818



816, Papilionaceous flower of the Pea. 817, Displayed; *v*, the vexillum; *a*, *a*, the alæ; *c*, *c*, the carinæ. 818, Section of flower of Dicentra Cucullaria.

475. Rotate, wheel-shaped or star-shaped, is a monpetalous form, with tube very short, if any, and a flat, spreading border, as the calyx of chickweed, corolla of Trientalis, elder. It is sometimes a little irregular, as in mullein.

476. Cup-shaped, with pieces cohering into a concave border, as in the calyx of mallows, corolla of Kalmia, etc.

477. Campanulate or bell-shaped; when the tube widens abruptly at base and gradually in the border, as in the harebell, Canterbury bell.

478. Urceolate, urn-shaped; an oblong or globular corolla with a narrow opening, as the whortleberry, heath.

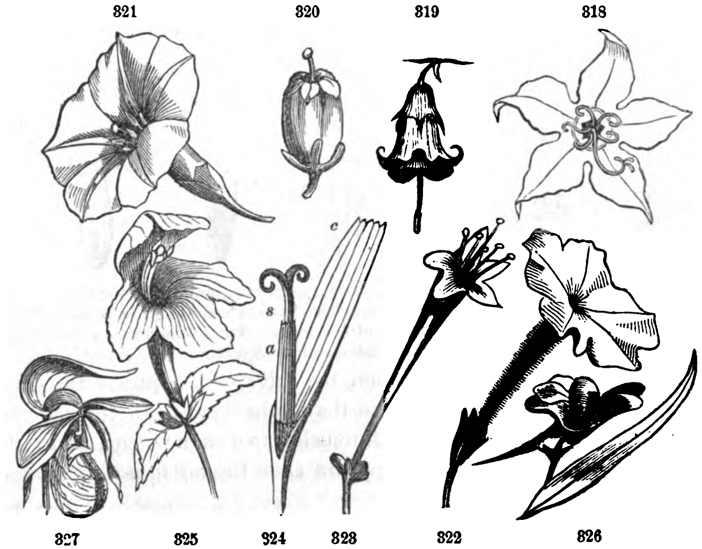
479. Funnel-form (infundibuliform), narrow tubular below, gradually enlarging to the border, as morning-glory.

480. Salver-form (hypocrateriform), the tube ending abruptly in a horizontal border, as in Phlox, Petunia, both of which are slightly irregular.

481. Tubular, a cylindraceous form spreading little or none at the border, as the calyx of the pink, corolla of the honeysuckle. It is often a little curved. Tubular flowers are common in the Compositæ, as the thistle, sunflower, when they are often associated with

482. Ligulate (*ligula*, a little tongue), apparently formed by the splitting of the tubular on one side. The notches at the end plainly indicate the number of united petals composing it, as also do the parallel, longitudinal seams.

483. Labiate, bilabiate, lip-shaped, resembling the mouth of an animal. This very common form results from the unequal union of the parts, accompanied with other irregularities. In the labiate corolla three petals unite more or less to form the lower lip, and two to form the upper. In the calyx, when bilabiate, this rule is reversed, accord-



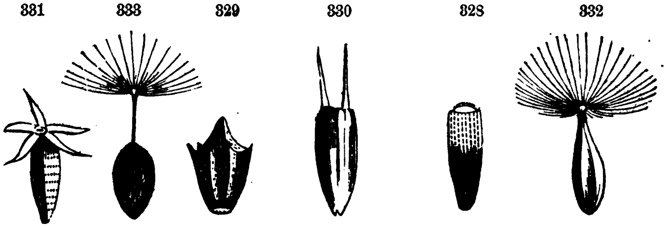
Forms of corollas. 818, Campanula Americana; rotate. 819, Campanula divaricata. 820 Andromeda, urceolate. 821, Convolvulus (morning-glory). 822. Petunia. 823, Lonicera sempervirens (honeysuckle). 824, Dandelion; ligulate corolla (*c*), 5-toothed; *a*, five anthers united into a tube around *s*, the style. 825, Synandra grandiflora, ringent, upper lip 2-lobed, lower 3-lobed. 826, Linaria (yellow snapdragon), personate. 827, Cypripedium acaule, orchidaceous.

ing to the law of alternation of organs; two sepals are united in the lower lip and three in the upper, as seen in the sage and the Labiate Order generally. Labiate flowers are said to be *galeate* or helmeted when the upper lip is concave, as in catmint; *ringent* or gaping when the throat or mouth is wide open; *personate* or masked when the throat is closed as with a *palate*, like the snapdragon.

484. Orchidaceous, a form of the perianth peculiar to the Orchis with that large and singular tribe in general. It is a 6-parted double perianth, very irregular, characterized chiefly by its *lip* (labellum), which is the upper petal (lower by the twisting of the ovary) enlarged and variously deformed.

Certain reduced forms of the perianth require notice here:

485. Pappus (πάππος, grandfather, alluding to his gray hairs) is a term applied to the hair-like calyx of the florets of the Compositæ and other kindred orders. The florets of this order are collected into heads so compactly that the calyxes have not room for expansion in the ordinary way. The pappus is commonly persistent and often increases as the fruit matures, forming a feathery sail to waft away the seed through the air, as in the dandelion and thistle. It varies greatly in form and size, as seen in the cuts, sometimes consisting of *scales*, sometimes of *hairs*, again of *feathers* or *bristles*. Sometimes it is mounted on a *stipe*, which is the beak of the fruit.



Cypsela (incorrectly called achenium) of the Compositæ, with various forms of pappus. 328, Eclipta procumbens, no pappus. 329, Ambrosia trifida. 330, Helianthus grosse-serratus, pappus 2-awned. 331, Ageratum conizoides, pappus of five scales. 332, Mulgedium, capillary pappus —cypsela slightly rostrate. 333, Lactuca elongata, rostrate cypsela.

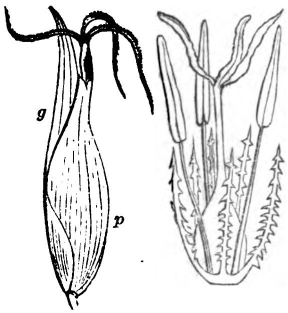
486. Other reductions. Again, the calyx or the limb of the calyx is reduced to a mere rim, as seen in the Umbelliferæ. In the amentaceous orders the whole perianth diminishes to a shallow cup, as in the poplar, willow, or altogether disappears, as in the birch, ash, lizard-tail. (264–267).

487. Setæ, meaning bristles in general, is a term specifically used to denote the reduced perianth of the sedges. In the bog-rush (Scirpus) there is, outside the stamens, a circle of six setæ, which doubtless represent a 6-leaved perianth. In the cotton-grass (Eriphorum) the setæ are multiplied and persistent on the fruit, becoming long and cotton-like.

488. **Perigynium** is the name given to the urceolate perianth of Carex, investing the ovary but allowing the style to issue at its summit. It is evidently composed of three united sepals.

489. **Glumes and pales** represent the floral envelops, or rather the involucre of the Grasses. Their alternating arrangement clearly distinguishes them from a perianth. They occur in pairs, the smaller usually above. The glumes envelop the spikelet, the pales the single flower, and often within the pales are two or three scales representing the perianth, surrounding the stamens and ovary, all which are illustrated in the wheat. (195.)

835 834



834, Flower of Scirpus lacustris, magnified; consisting of six setæ, three stamens, three pistils united, except the stigmas. 835, Flower of Carex rivularis ♀, with *g*, its glume, *p*, its bottle-shaped perigynium, 3-toothed at top, enveloping the triple ovary; stigmas, three.

490. **The duration** of the calyx and corolla varies widely, and is marked by certain general terms. It is *caducous* when it falls off immediately, as the calyx of poppy, corolla of grape; *deciduous* when it falls with the stamens, as in most plants; and *persistent* if it remain until the fruit ripens, as the calyx of apple. If it continue to grow after flowering, it is *accrescent*, and if it wither without falling off it is *marescent*.

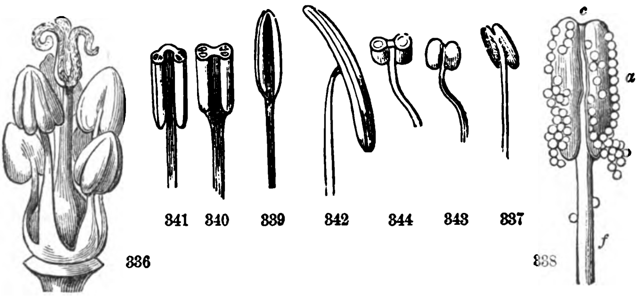
CHAPTER XII.

OF THE ESSENTIAL ORGANS.

§ THE STAMENS, OR ANDRŒCIUM.

491. **Position.** Within the safe inclosure of the floral envelops stand the essential organs—the stamens and pistils, clearly distinguishable from the perianth by their more slight and delicate forms, and from each other by various marks. In the complete flower the andrœcium next succeeds the corolla in the order of position, being the third set, counting from the calyx.

492. A **perfect stamen** consists of two parts—the *filament*, corresponding with the petiole of the typical leaf, and the *anther*, answering to the blade. Within the cells of the anther the *pollen* is produced, a substance essential to the fertility of the flower. Hence the anther alone is the essential part of the stamen.



Andrœcium (and gynœcium) of Frankenia (after Peyer). 837, Stamen (adnate) of morning-glory. 838, Same enlarged, with pollen grains discharged; *f*, filament; *a*, *a*, anther, 2-lobed; *c*, top of the connectile. 839, Ranunculus. 840, Same, cut transversely. 841, Iris cut transversely (extrorse). 842, Amaryllis, versatile. 843, Larkspur, innate. 844, Same, cut.

493. THE FILAMENT (*filum*, a thread) is the stalk supporting the anther at or near its top. It is ordinarily slender and filiform, yet firmly sustaining itself with the anther in position. Sometimes it is *capillary* and pendulous with its weight, as in the Grasses.

494. THE ANTHER is regularly an oblong body at the summit of the filament, composed of two hollow parallel lobes joined to each other and to the filament by the *connectile*. In front of the connectile, looking toward the pistil, there is usually a furrow; on its back a ridge, and on the face of each lobe a seam, the usual place of *dehiscence* or opening, all running parallel with the filament and connectile.

The stamen, as thus described, may be considered regular or typical in form, and is well exemplified in that of the buttercup (Fig. 339). But the variations of structure are as remarkable here as in other organs, depending on circumstances like the following—

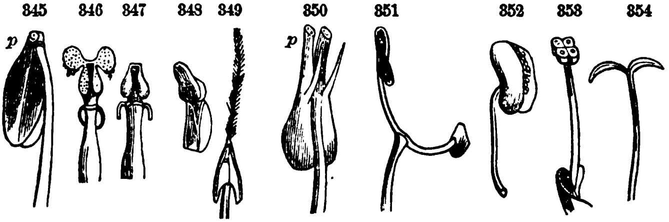
495. ATTACHMENT OF FILAMENT TO ANTHER. This may occur in three ways. The anther is said to be *innate* when it stands centrally erect on the top of the filament, *adnate* when it seems attached to one side of the filament, *versatile* when connected by a single point in the back to the top of the filament.

496. DEHISCENCE, or the modes of opening, are also three, viz., *valvular*, where the seam opens vertically its whole length, which is the usual way; *porous* where the cells open by a chink or pore usually at the top, as in Rhododendron and potato; *opercular* when by a lid opening upward, as in sassafras, berberis. (346.)

497. THE FACING OF THE ANTHER is also an important character. It is *introrse* when the lines of dehiscence look toward the pistil, as in violet; *extrorse* when they look outward toward the corolla, as in Iris.

498. THE CONNECTILE is usually a mere prolongation of the filament, terminating, not at the base, but at the top of the anther. If it fall short, the anther will be *emarginate*. Sometimes it outruns the anther and tips it with a terminal appendage of some sort, as in violet, oleander, Paris. Again, its base may be dilated into spurs, as in two of the stamens of violet.

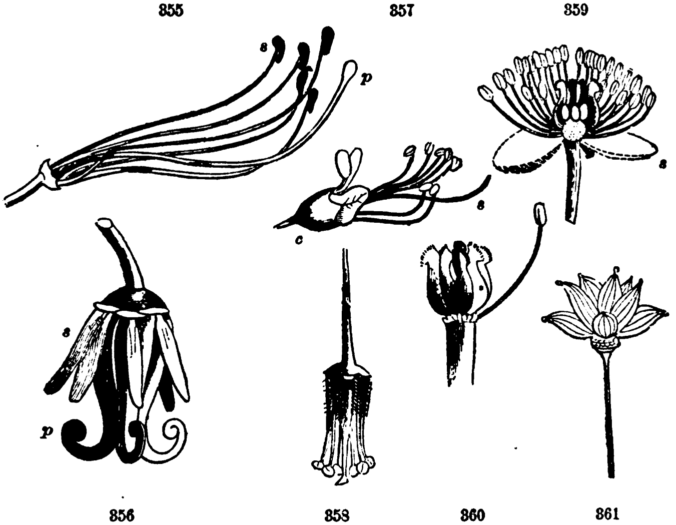
499. DIMIDIATE ANTHER. If the connectile be laterally dilated, as we see gradually done in the various species of the Labiate Order, the lobes of the anther will be separated, forming two *dimidiate* anthers (halved anthers) on one filament, as in sage, Prunella. Such are, of course, 1-celled. (351.)



Peculiar forms of stamens. 345, Pyrola rotundifolia; *p*, dehiscence by pores at top. 350 Vaccinium uliginosum; *p*, dehiscence. 347, Berberis aquifolium, anthers opening (346) by valves upward. 348, Anther of Violet, introrse, with an appendage at top. 349, Oleander, sagittate, appendaged. 354, Catalpa, lobes of anther separated. 351, Sage, lobes of anther widely separated, on stipes; *b*, barren lobe without pollen. 352, Malva, anther 1-celled. 353, Ephedra (after Peyer), anther 4-celled.

500. THE CELLS OF THE ANTHERS are at first commonly four, all parallel, becoming two only at maturity. In some plants the four are retained, as in the anthers of Ephedra. (353.) In others, as mallows, all the cells coalesce into one. (352.)

501. APPENDAGES of many kinds distinguish the stamens of different species. In the Ericaceæ there are horns, spurs, tails, queues, etc. In onions and garlic the filament is 2 or 3-forked, bearing the anther on one of the tips. Sometimes a pair of appendages appear at base, as if stipulate. It is often conspicuously clothed with hairs, as in Tradescantia.



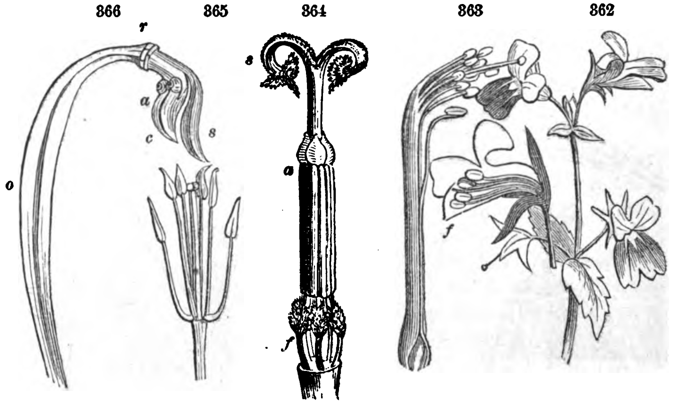
Essential organs. 355, Rhododendron, five stamens (*s*), one pistil (*p*), oblique or slightly irregular. 357, Flower of Æsculus (Buckeye), regular, 5-toothed calyx (*c*), very irregular 4-petaled corolla, seven stamens unequal, one style (*s*). 359, Flower of Hydrastis; *s*, sepals deciduous. 360, Same, showing the distinct pistils and one stamen remaining. 361, Anemone thalictroides, the gynœcium of distinct, ribbed achenia. 356, Trillium, six stamens (*s*), three pistils (*p*). 358, Staphylea trifolia.

502. **Staminodia**, or sterile filaments with abortive anthers or none, occur singly in many of the Figworts and Labiates, or in entire whorls next within the petals, alternating with them, as in loose-strife; in all cases restoring the symmetry of the flowers. They are generally reduced in size, as in Scrophularia, rarely enlarged, as in beardtongue (Pentstemon).

503. **The number** of the stamens is said to be *definite* when not exceeding twenty, as is sometimes definitely expressed by such terms as follow, compounded by the Greek numerals, viz., *monandrous*, having *one* stamen to each flower; *diandrous*, with two stamens; *pentandrous*, with five stamens. If the number exceeds twenty, it is said to be *indefinite* (denoted thus, ∞) or polyandrous.

504. **The position** or insertion of the stamens (§ 463) may be more definitely stated here, as *hypogynous*, on the receptacle below the ovaries; *perigynous*, on the calyx around the ovary; *epipetalous*, on the corolla, as in Phlox; *epigynous*, on the ovary at its summit, and *gynandrous* (γυνὴ, pistil, ἀνδρες, stamens) on the pistil, that is, when the stamens are adherent to the style, as in Orchis.

505. **Inequality in length** is definitely marked in two cases, as *tetradynamous* (τετρὰς, four, δὺναμις, power) when the stamens are six, whereof four are longer than the other two, as in all the Crucifers; *didynamous*, where the stamens are four, two of them longer than the other two, as in all the Labiates, etc.



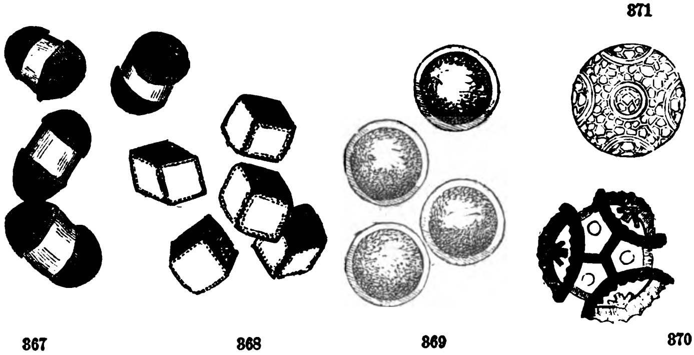
862, Collinsia verna: *f*, a flower enlarged, cut, showing the slightly didynamous stamens, etc. 863, Stamens (diadelphous) of a Leguminous plant. 864, Stamens (syngenecious) of a Composite; *f*, filaments distinct; *a*, anthers united; *s*, stigmas revolute, etc. 865, Tetradynamous stamens of a Crucifer. 866, Gynandrous column of Cypripedium; *o*, ovary; *r*, torus; *s*, sterile stamen; *a*, two pollinia; *c*, stigma.

506. **Cohesion** is as frequent with stamens as with petals. They are *monadelphous* (ἀδελφός, a brother) when they are all united, as in mallow, into one set or brotherhood by the filaments; *diadelphous* in two sets, whether equal or unequal, as in pea, squirrel-corn; *polyadel-*

phous, many sets, as in St. John'swort; and *syngenesious*, when they are united by their anthers, as in the Compositæ. Finally,

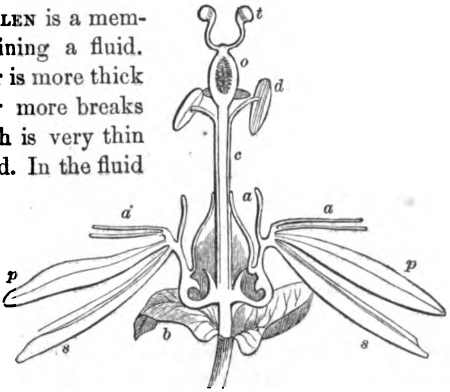
507. THE ABSENCE of the stamens altogether, whether by abortion, as in the ♀ flowers of Veratrum, or by suppression, as in oak, occurs in various modes, rendering the plant monœcious (☿), diœcious (♂ ♀), or polygamous (♂ ☿ ♀), as already explained (§ 421).

508. THE POLLEN is in appearance a small, yellow dust, contained in the cells of the anther. When viewed with the microscope it appears as grains of various forms, usually spheroidal, or oval, sometimes triangular or polyhedral, but always of the same form and appearance in the same species. Externally they are curiously, and often elegantly figured with stripes, bands, dots, checks, etc.



Pollen grains. 867, Pinus larico. 868, Basella rubra. 869, Ranunculus repens. 870, Scolymus grandiflorus. 871, Passiflora incarnata.

509. EACH GRAIN OF POLLEN is a membranous cell or sack containing a fluid. Its coat is double, the outer is more thick and firm, exhibiting one or more breaks where the inner coat, which is very thin and expansible, is uncovered. In the fluid are suspended molecules of inconceivable minuteness, said to possess a tremulous motion. When the membrane is exposed to moisture it swells and bursts, discharging its contents.



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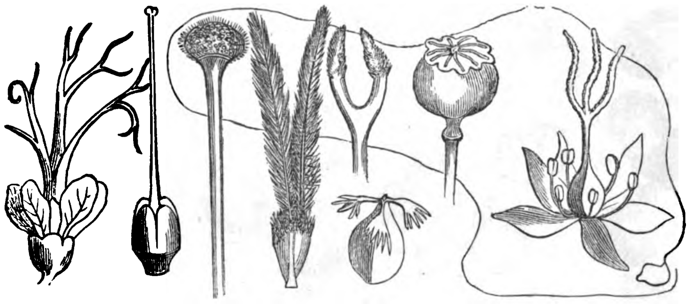
872, Section of the Passion-flower (Passiflora cœrulea); *b*, bracts of the involucre; *s*, sepals; *p*, petals; *a*,*a*, staminodia or sterile filaments; *c*, stipe; *o*, ovary; *d*, stamens; *t*, stigmas.

510. POLLINIA. In the Orchids and Silkweed

tribe, the pollen grains do not separate as into a dust or powder, but all cohere into masses called pollinia, accompanied by a viscid fluid.

THE PISTILS, OR GYNŒCIUM.

511. POSITION. The Gynœcium occupies the center of the flower at the termination of the axis. It consists regularly of a circle of distinct pistils, (§ 405), symmetrical in number with the other circles. It is subject to great variation. The pistil may be distinct and *simple*, as in columbine, or coherent in various degrees into a *compound* body, as in St. John's wort.



Pistils. 872, Symphytum, basilar style, ovary 4-parted. 871, ♀ Fl. of Emblica (Euphorbiaceæ), branching styles. 873, Mirabilis Jalapa, globular stig. 877, Fl. of Luzula, stigmas linaer. 874, Feathery stigmas of a grass. 879, Stigmas of Aster. 875, Rumex. 876, Poppy. 878, Filiform stigma of Zea Mays, (Corn).

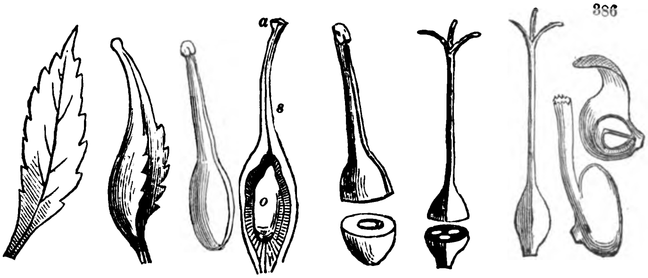
512. EXCEPTION. Also instead of being free and superior, as it regularly should be, it may adhere to the other circles, as already explained (§ 462), and become *inferior*, that is, apparently placed below the flower, as in the currant.

513. THE NUMBER of the pistils is by no means confined to the radical of the flower. They may be increased by multiples, becoming a *spiral* on a lengthened receptacle, as in tulip-tree, or still remaining a circle, as in poppy. On the other hand they may be reduced in number often to one, as in cherry, pea. Certain terms are employed to denote the number of pistils in the flower, such as *monogynous*, with one pistil, *trigynous*, with three, *polygynous*, with many, etc.

514. THE SIMPLE PISTIL may usually be known from the compound, by its one-sided forms—having two sides similar and two dissimilar. If the pistils appear distinct, they are all simple, never being united into more than one set, as the stamens often are.

515. The parts of a simple pistil are three, the *ovary* at base, the *stigma* at the summit, and the *style*, intervening. Like the filament the style is not essential, and when it is wanting, the stigma is ***sessile*** upon the ovary, as in crowfoot. In order to understand the relation of these parts we must needs first study

516. The morphology of the pistil. As before stated, (§ 380), the pistil consists of a modified leaf called a carpel (καρπὸς, fruit), or *carpellary* leaf. This leaf is folded together (induplicate) toward the axis, so that the upper surface becomes the inner, while the lower becomes the outer surface of the ovary. By this arrangement two ***sutures*** or seams will be formed, the *dorsal*, at the back by the midvein, the ***ventral***, in front by the joined margins of the leaf.



378 bis 379 bis 380 381 382 383 384 385

385, Simple pistil of Strawberry, the style lateral. 386, Simple pistil of Crowfoot, cut to show the ovule. 380, Simple pistil of the Cherry. 381, Vertical section showing the ovule (*o*), style (*s*), stigma (*a*). 382, Cross-section of the same. 384, Compound pistil of Spring-beauty. 383, Cross-section of the same showing the 3 cells of the ovary. 378, Expanded carpellary leaf of the double cherry. 379, The same partly folded as if to form a pistil.

517. Illustration. This view of the pistil is remarkably confirmed and illustrated by the flowers of the double cherry, where the pistil may be seen in every degree of transition, reverting toward the form of a leaf. This carpellary leaf stands in the place of the pistil, having the edges infolded toward each other, the midvein prolonged and dilated at the apex.

518. If this be compared with the pistil of the cherry seen in the figure (378, 379), no doubt can be entertained that the two sides of the leaf correspond to the walls of the ovary, the margins to the ventral suture, the midvein to the dorsal suture, and the lengthened apex to the style and stigma. Sometimes the flower contains two such leaves, which always present their faces toward each other. This corresponds to the position of the true carpels, in which the ventral sutures of both are contiguous.

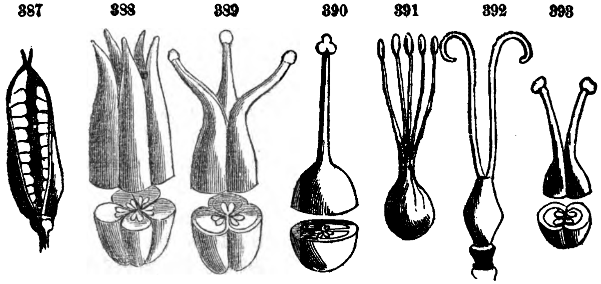
519. The doctrine deduced. Many other plants, as the rose, Anemone, Ranunculus, flowering almond, exhibit similar transformations of the pistil, making it probable that it is formed upon the same plan in all plants. The ovary, therefore, is the blade of a leaf, folded into a sack; the style is the lengthened apex folded into a tube; the stigma, a thickened and denuded portion of the upper margin of the leaf.

520. THE PLACENTÆ are usually prominent lines or ridges extending along the ventral suture within the cell of the ovary, and bearing the ovules. They are developed at each of the two edges of the carpellary leaf, and are consequently closely parallel when those edges are united, forming one double placenta in the cell of each ovary.

521. THE SIMPLE CARPEL, with all its parts, is completely exemplified in the pea-pod. When this is laid open at the ventral suture, the leaf form becomes manifest, with the peas (ovules) arranged in an alternate order along each margin, so as to form but one row when the pod is closed. In the pod of columbine the ovules form two distinct rows; in the simple plum carpel each margin bears a single ovule, and in the one-ovuled cherry only one of the margins is fruitful.

522. THE STIGMA is the glandular orifice of the ovary, communicating with it either directly or through the tubiform style. It is usually globular and terminal, often linear and lateral, but subject to great variations in form. It is sometimes double or halved, or 2-lobed, even when belonging to a single carpel or to a simple style, as in Linden, where these carpels are surmounted by three pairs of stigmas.

523. THE COMPOUND PISTIL consists of the united circle of pistils, just as the monopetalous corolla consists of the united circle of petals. The union occurs in every degree, always commencing at the base of the ovary and proceeding upward. Thus in columbine we see the carpels (pistils) quite distinct; in early saxifrage cohering just at base; in pink as far as the top of the ovaries, with styles distinct; in evening primrose to the top of the styles, with stigmas distinct; and in Rhododendron the union is complete throughout.



387, Ovary (follicle) of Larkspur, composed of single carpellary leaf. 388, Ovaries of the Columbine, five, contiguous but distinct 389, Compound ovary of Hypericum, of carpels united below with distinct styles. 390, Ovary of another Hypericum of three carpels completely united. 391, Ovary of Flax; carpels five, united below, distinct above. 392, Dianthus (Pink). 393, Saxifraga.

524. TO DETERMINE THE NUMBER OF CARPELS in a compound ovary is an important matter. It may be known, 1, by the number of styles; 2, by the number of free stigmas (remembering that these organs are liable to be halved, § 522); 3, by the lobes, angles, or seams of the ovary; 4, by the cells; 5, by the placenta.

525, TWO MODES OF COHESION in the carpellary circle greatly affect the structure of the ovary and fruit. *First* and regularly, the carpels may be *closed* as when simple, and conjoined by their sides and fronts, as in lily and marsh mallow. In this case,

1, The compound ovary will have as many cells as carpels.

2, The partitions between the cells, *i. e.*, the *dissepiments* (*dissepio*, to separate) will each be double, will meet in the center, will be vertical and alternate with the stigmas.

3, The single carpel can have no true dissepiment. If any ever occur it is regarded as *spurious*, being a membranous expansion of the dorsal suture or the placentæ, as in flax.

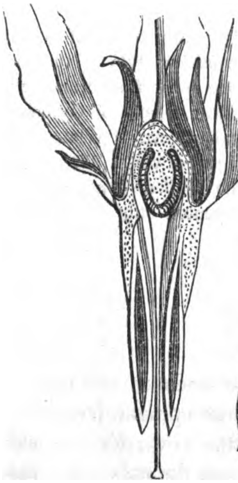
4, The placentæ as well as the ventral suture will be *axial*, and the dorsal suture on the outer wall, opposite the stigmas.

526. AGAIN, the carpels may each be open and conjoined by their edges, as the petals in a monopetalous corolla. So it is in the compound ovary of the violet, rock-rose. In this case,

1, There will be no dissepiment (unless spurious, as in the Cruciferæ), and but one cell.

2, The placentæ of each carpel will be separated and carried back to the wall of the ovary, *i. e.*, they will become *parietal* (*paries*, a wall.)

527. INTERMEDIATE CONDITIONS. Between the two conditions of axile (or central) and parietal placentæ we find all degrees of transition, as illustrated in the different species of St. John'swort, and in poppy, where the inflected margins of the carpels carry the placentæ inward, well nigh to the axis. Moreover, the placentæ are not always mere marginal lines, but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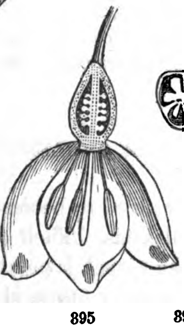
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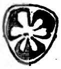
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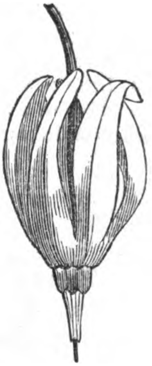
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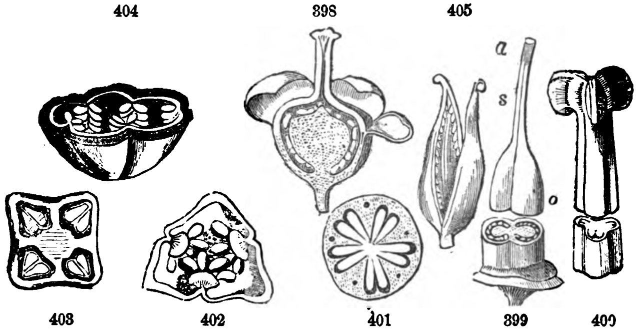
897, Flower of Dodecatheon Meadia. 894, Vertical section showing the free central placenta. 895, Vertical section of Lucojum (Snow-drop). 896, Cross section of ovary.

often wide spaces covering large portions of the walls of the cell, as in poppy, water-lily, and in other cases, as Datura, they become large and fleshy, nearly filling the cell.

528. A **FREE AXILE PLACENTA**, without dissepiments, occurs in some compound, one-celled ovaries, as in the pink and primrose orders. This anomaly is explained in two ways: first, by the obliteration of the early formed dissepiments, as is actually seen to occur in the pinks; secondly, by supposing the placenta to be, at least in some cases, an *axial* rather than a marginal growth; that is, to grow from the point of the axis rather than from the margin of the carpellary leaf, for in primrose no dissepiments ever appear.



398. Samolus Valorandi, section of flower showing the free axile placenta. 399, Ovary of Scrophulariaceæ. 400, Ovary of Tulip. 401, Cross-section of ovary of Flax, 5-celled, falsely 10-celled. 402, Ovary of Violet, 1-celled. 403, Ovary of Fuchsia, 4-celled. 404, Ovary of rock-rose, 1-celled, 5-carpelled. 405. Gentianaceæ, 2-valved, 1-celled.

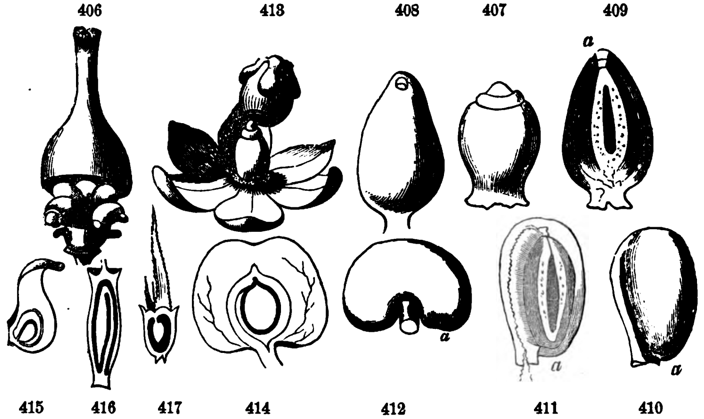
529. A **FEW PECULIAR FORMS** of the style and stigma are worthy of note in our narrow limits, as the *lateral* style of strawberry, the *basilar* style of the Labiatæ and Borrageworts, the branching style of Emblica, one of the Euphorbiaceæ; also,

530. **THE GLOBULAR STIGMA** of Mirabilis; the linear stigma of Gyromia; the feathery stigma of grasses; the filiform stigma of Indian corn; the lateral stigma of Aster; the petaloid stigmas of Iris; the hooded stigma of violet (371—379).

531. **STIGMA WANTING.** In the pine, cedar, and the Coniferæ generally, both the style and stigma are wanting, and the ovary is represented only by a flat, open, carpellary scale bearing the naked ovules at its base.

THE OVULES.

532. **THEIR NATURE.** Destined to become seeds in the fruit ovules are understood to be altered buds. Their development from the margins and inner surface of the carpel favors this view; for the ordinary leaves of Bryophyllum and some other plants do habitually produce buds at their margin or on their upper surface; and in the mignonette ovules themselves have been seen transformed into leaves.



406, Pistil of Celosia, the pericarp detached showing the young ovules. 413, Flower of Rhubarb; pericarp removed showing the young ovule. 407, A similar ovule (orthotropous) of Polygonum. 408, The same, full grown; foramen at top. 409, Section showing its two coats, nucleus and sac. 410, Anatropous ovule, as of columbine; *a*, foramen. 411, Section of same. 412, Campylotrópous ovule, as of Bean; *a*, foramen. 414, Section of a cherry, ovule anatropous, suspended. 415, Section of carpel of Ranunculus; ovule ascending. 416, Senecio; ovule erect. 417, Hippuris; ovule pendulous.

533. THE NUMBER of ovules in the ovary varies from one to hundreds. Thus in buttercups, Compositæ and grasses the ovule is *solitary;* in Umbeliferæ it is also solitary in each of the two carpels; in the Pea Order they are *definite*, being but few; in Mullein, Poppy, *indefinite* (∞), too many to be readily counted.

534. THE POSITION of the ovule in the cell is defined by certain terms as follows; *erect*, when it grows upwards from the base of the cell, as in Compositæ; *ascending*, when it turns upwards from its point of lateral attachment; *horizontal*, when neither turning upwards nor downwards; *pendulous*, when turned downwards, and *suspended*, when growing directly downwards from the top of the cell, as in birch. (315, 316, 317, 319).

535. THE OVULE AT THE TIME OF FLOWERING is soft and pulpy, consisting of a nucleus within two coats, supported on a stalk. The stalk is called *funiculus;* the point of its juncture with the base of the nucleus is the *chalaza.* The *nucleus* was first formed, then the *tegmen* or inner coat grew up from the chalaza and covered it, and lastly the outer coat, the *testa*, invested the whole. Both coats remain open at the top by a small passage, the micropyle.

536. CHANGE OF POSITION. In most cases the ovule, in the course of its growth, changes position, curving over in various degrees upon its lengthening funiculus or upon itself. When no such curvature exists, and it stands straight, as in the buckwheat order, it is *orthotropous.* It is

537. **Anatropous** when completely inverted. In this state a portion of the funiculus adheres to the testa, forming a ridge called *raphe*, reaching from the chalaza to the *hilum*.

538. **It is campylotropous** when curved upon itself. In this state the micropyle is brought near to the chalaza, and both are next the placenta, as in the pinks and Cruciferæ.

539. **Amphitropous** when half inverted, so that its axis becomes parallel with the placenta, as in mallow. Here the raphe exists, but is short. In campylotropous there is no raphe.

The ovule contains no young plant (embryo) yet; but a cavity, the *embryo sac*, is already provided to receive it just within the upper end of the nucleus.

540. **The relations of the ovule to the pollen grain** will be more suitably discussed hereafter under the head of fertilization. We briefly remark here that the immediate contact of the two is brought about at the time of flowering by special arrangements; and that, as the undoubted result of their combined action, the embryo soon after originates in the embryo sac.

CHAPTER XIII.

THE FRUIT.

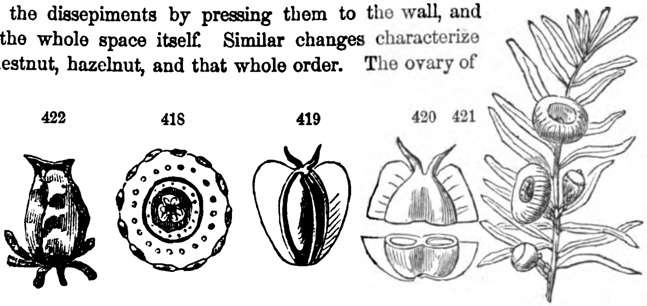
541. **Its origin.** After having imbibed the pollen which the anthers have discharged, the pistil or its ovary continues its growth and enlargement, and is finally matured in the form of the peculiar fruit of the plant. The fruit is, therefore, properly speaking, *the ovary brought to perfection.*

542. **State of the other parts in fruit.** The other organs of the flower, having accomplished their work, the fertilization of the ovary, soon wither and fall away. Some of them, however, often persist, to protect or become blended with the ripening fruit. Thus the tube of the *superior* calyx (§ 446) always blends with the ovary in fruit, as in currant, cucumber, apple, etc. In Compositæ the persistent *limb* enlarges into the pappus of the fruit. In buttercups the fruit is *beaked* with the short, persistent *style.* In Clematis, Geum, it is *caudate* (tailed) with the long, growing *style.* In the Potato tribe, Labiatæ, and many others, the *inferior calyx* continues to vegetate like leaves until the fruit ripens.

543. **Consolidated fruit.** In some cases the fruit, so-called, consists of the receptacle and ovaries blended, as in blackberry, strawberry. Again, in mulberry, fig, pine-apple, the whole inflorescence is consolidated into the matured fruit.

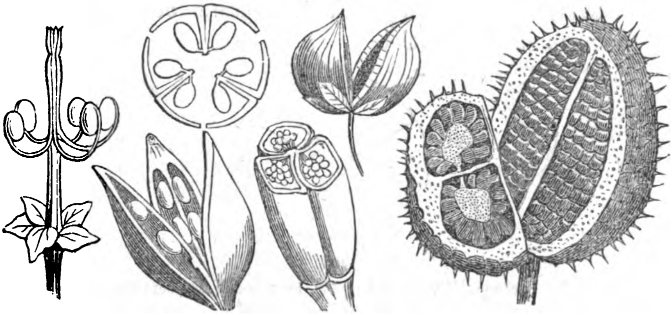
544. **A rule and exception.** As a rule, the structure of the fruit agrees essentially with that of the ovary. In many cases, however, the fruit undergoes such changes in the course of its growth from the ovary as to disguise its real structure. An early examination, therefore, is always more reliable in its results than a late one.

545. For example, the oak-acorn is a fruit with but one cell and one seed, although its ovary had three cells and six ovules! This singular change is due to the non-development of five of its ovules, while the sixth grew the more rapidly, obliterated the dissepiments by pressing them to the wall, and filled the whole space itself. Similar changes characterize the chestnut, hazelnut, and that whole order. The ovary of the birch is 2-celled, 2-ovuled; but by the suppression of one cell with its ovule, the fruit becomes 1-celled and 1-seeded.



418, Section of the ovary of an acorn, 3-celled, 6-ovuled. 420, Section of ovary of Birch, 2-celled, 2-ovuled. 419, Vertical section of the same in fruit. 422. Pericarp of Mignionette open soon after flowering. 421, Naked seed of Taxus Canadensis, surrounded, not covered by the fleshy pericarp.

546. On the other hand the cells are sometimes multiplied in the fruit by the formation of false partitions. Thus the pod of thorn-apple (Datura) becomes 4-celled from a 2-celled ovary, and the longer pods of some leguminous plants have cross-partitions formed between the seeds.



Capsule, 427, of Scrophularia, 2-celled; 423, of Datura Stramonium; 425, of Iris; 426, showing its mode of dehiscence (loculicidal); 424, of Colchicum, 3-celled. 428, Regma, ripe fruit of Geranium, the carpels (cocci) separating from the axis and bending upwards on the elastic styles.

PERICARP.

The fruit consists of the pericarp and the seed.

547. The pericarp (περί, around) is the envelope of the seeds, consisting of the carpels and whatever other parts they may be combined with. It varies greatly in texture and substance when mature, being

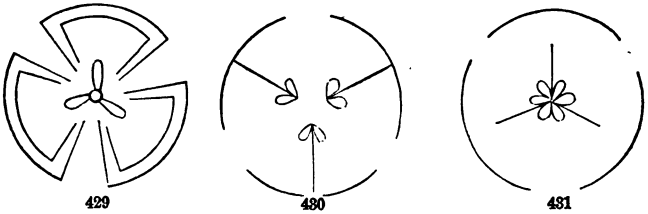
then either dry, as the pea-pod, or *succulent*, as the currant. Dry pericarps are *membranous*, or *coriaceous* (leathery), or *woody*. Succulent pericarps may be either wholly so, as the grape, or partly so, as the peach and other stone fruit.

548. Pericarp closed or open. With very few exceptions the pericarp encloses the seed while maturing. In mignonette (322), however, it opens, exposing the seed, immediately after flowering. The membranous pericarp of cohosh (Leontice) falls away early leaving the seed to ripen naked. In yew (Taxus) the seed is never enclosed wholly by its fleshy pericarp.; but in most of the other Coniferæ, the close-pressed, carpellary scales cover the seeds. One-seeded fruits, like those of butter-cups, etc., are liable to be mistaken for naked seeds.

549. Dehiscence. The fleshy pericarp is always *indehiscent.* Its seeds are liberated only by its decay, or bursting in germination. So also in many cases the dry pericarp, as the acorn. But more commonly the dry fruit, when arrived at maturity, opens in some way, discharging its seeds. Such fruits are dehiscent.

550. Modes. Dehiscence is either valvular, porous, or circumscissile; *valvular*, when the pericarp opens vertically along the sutures, forming regular parts called *valves.* These valves may separate quite to the base, or only at the top, forming teeth, as in chickweed. We notice four modes of valvular dehiscence, viz.:

1, *Sutùral*, when it takes place at the sutures of any 1-celled pericarp, as columbine, pea, violet.



Dehiscence; 429, septicidal; 430, loculicidal; 431, septifragal.

2, *Septicidal* (*septum*, partition, *cædo*, to cut), when it takes place through the dissepiments (which are double, § 525). The carpels thus separated may open severally by sutures, (Mallows), or remain indehiscent, as in Vervain.

3, *Loculìcidal* (*loculus*, a cell, *cædo*, to cut), when each carpel opens at its dorsal suture directly into the cell (evening-primrose, lily). Here the dissepiments come away attached to the middle of the valves.

4, *Septìfragal* (*septum*, and *frango*, to break), when the valves separate from the dissepiments which remain still united in the axis (Convolvulus).

551. Porous dehiscence is exemplified in the poppy, where the seeds escape by orifices near the top of the fruit. It is not common.

552. Circumscissile (*circumscindo*, to cut around), when the top of the ovary opens or falls off like a lid, as in Jeffersonia, henbane, plantain.

553. Carpophore. Some fruits, as the Gerania and Umbeliferæ, are furnished with a *carpophore*, that is, a slender column from the receptacle, prolonged through the axis of the fruit, supporting the carpels.

554. The morphology of the pericarp is exceedingly diversified, but it will suffice the learner at first to acquaint himself with the leading forms only, such as are indicated in the following synopsis and more definitely described afterward.

555. The following is a synopsis of the principal forms of Pericarps.

§ 1. FREE FRUITS (FORMED BY A SINGLE FLOWER).

* Pericarps indehiscent,	
† With usually but one seed, and	
‡ Uniform, or 1-coated.	
1. Separated from the seed.	Achenium (buttercups).
2. Inflated, often breaking away.	Utricle (pigweed).
3. Inseparable from the seed.	Caryopsis (grasses).
4. Invested with a cupule (involucre).	Glans (oak).
5. Having winged appendages.	Samara (ash).
Double or triple-coated, fleshy or fibrous.	
6. Three-coated. Stone cell entire.	Drupe (cherry).
7. Two-coated. Stone cell 2-parted.	Tryma (walnut).
8. Drupes aggregated.	Etærio (raspberry).
† With two or more seeds,	
‡ Immersed in a fleshy or pulpy mass.	
9. Rind membranous.	Berry (gooseberry).
10. Rind leathery, separable.	Hesperidum (orange).
11. Rind hard, crustaceous.	Pepo (squash)
‡ Inclosed in distinct cells.	Pome (apple).
* Pericarps dehiscent.	
12. Dehiscence circumscissile. seeds ∞ .	Pyxis (henbane).
† Dehiscence valvular or porous;	
‡ Simple or 1-carpeled,	
13. Opening by the ventral suture.	Follicle (columbine).
14. Opening by both sutures.	Legume (pea).
15. Legume jointed.	Loment (Desmodium).
‡ Compound pericarps;	
16. Placentæ parietal with two cells.	Silique (mustard).
Silique short.	Silicle (shepherd's purse).
17. Placentæ parietal only when 1-celled.	Capsule (flax).
18. Capsule with carpophore and elastic styles.	Regma (Geranium).

§ 2. CONFLUENT FRUITS (FORMED OF AN INFLORESCENCE).

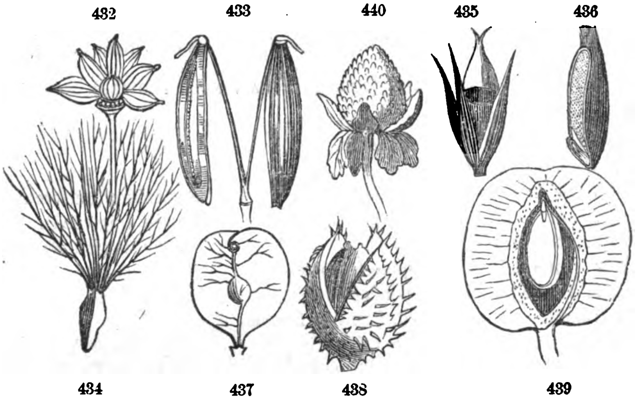
* With open carpels aggregated into a cone.	Strobile (pine).

* With closed carpels aggregated into a mass, as in the fig, mulberry, Osage-orange, pine-apple, etc.

556. **The achenium** is a small, dry, indehiscent pericarp, free from the one seed which it contains, and tipped with the remains of the style (buttercups, Lithospermum).

557. The double achenium of the Umbeliferæ, supported on a *carpophore* is called *cremocarp*. The 2-carpeled achenium of the Compositæ, usually crowned with a pappus, is called *cypsela*.

558. **The achenia are often mistaken** for seeds. In the Labiatæ and Borrageworts they are associated in fours (372). In Geum, Anemone, etc., they are collected in heads. The rich pulp of the strawberry consists wholly of the overgrown receptacle, which bears the dry achenia on its surface. (440).



432, Achenia of Anemone thalictroides. 433, Cremocarp of Archangelica officinalis, its halves (*merocarps*) separated and suspended on the *carpophore*. 434, Cypsela of Thistle with its plumous pappus. 435, Utricle of Chenopodium (pigweed). 436, Caryopsis of Wheat. 437, Samara of Elm. 438, Glans of Beech. 439, Drupe of Prunus. 440, Fruit of Fragaria Indica, a fleshy torus like the strawberry.

559. **The utricle** is a small, thin, pericarp fitting loosely upon its one seed, and often opening transversely to discharge it (pigweed, prince's feather).

560. **Caryopsis**, the grain or fruit of the grasses, is a thin, dry, 1-seeded pericarp, inseparable from the seed.

561. **Samara**; dry, 1-seeded, indehiscent, furnished with a membranous wing or wings (ash, elm, maple).

562. **Glans or nut**; hard, dry, indehiscent, commonly 1-seeded by suppression (§ 545), and invested with a persistent involucre called a *cupule*, either solitary (acorn, hazelnut) or several together (chestnut, beechnut).

563. **Drupe**, stone-fruit; a 3-coated, 1-celled, indehiscent pericarp, exemplified in the cherry, peach. The outer coat (epidermis) is called the *epicarp*, the inner is the *nucleus* or *endocarp*, hard and stony; the intervening pulp or fleshy coat is the *sarcocarp* (σὰρξ, flesh). These coats are not distinguishable in the ovary.

564. **Tryma**, a kind of dryish drupe, 2-coated, the epicarp fibro-fleshy (butternut) or woody (hickory), the nucleus bony with its cell often deeply 2-parted (cocoa-nut).

565. **Etærio**, an aggregate fruit consisting of numerous little drupes united to each other (raspberry) or to the fleshy receptacle (blackberry).

566. **Berry**, a succulent, thin-skinned pericarp holding the seeds loosely imbedded in the pulp (currant, grape).

567. **Hesperidum**, a succulent, many-carpeled fruit, the rind thick, leathery, separable from the pulpy mass within (orange, lemon).

568. **Pepo**, an indehiscent, compound, fleshy fruit, with a hardened rind and parietal placentæ (melon).

569. **The pome** is a fleshy, indehiscent pericarp formed of the permanent calyx, containing several cartilaginous (apple) or bony (haw) cells.

570. **The pyxis** is a many-seeded, dry fruit, opening like a lid by a circumcissile dehiscence (plantain, henbane, Jeffersonia).

571. **The follicle** is a single carpel, 1-celled, many-seeded, opening at the ventral suture (columbine, larkspur, silk-grass).

572. **The legume** or pod is a single carpel, 1-celled, usually splitting into two valves, but bearing its 1–∞ seeds along the ventral suture only, in one row, as in the bean and all the Leguminosæ. It is sometimes curved or coiled like a snail-shell (Medicago).

573. **The loment** is a jointed pod, separating across into 1-seeded portions (Desmodium).

574. **Silique.** This is also a pod, linear, 2-carpeled, 2-valved, 2-celled by a false dissepiment extended between the two parietal placentæ. To this false dissepiment on both sides of both edges the seeds are attached (mustard).

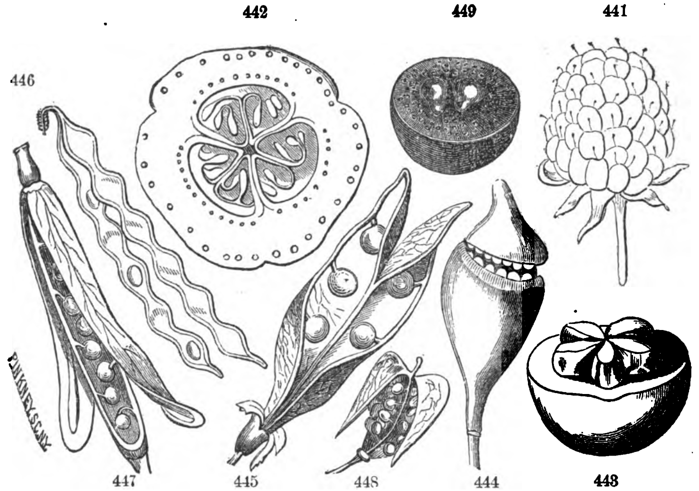
575. **Silicle.** This is a short silique, nearly as wide as long (shepherd's purse). The silique and silicle are the peculiar fruit of all the Cruciferæ.

576. **Capsule** (casket). This term includes all other forms of dry, dehiscent fruits, compound, opening by as many valves as there are carpels (Iris), or by twice as many (chickweed), or by pores (poppy).

577. **The regma** is a kind of capsule like that of the Geranium, whose dehiscent carpels separate elastically but still remain attached to the carpophore.

578. **Strobile or cone**; an aggregate fruit consisting of a conical or oval mass of imbricated scales, each an open carpel (♀ flower), bearing seeds on its inner side at base, *i. e.*, axillary seeds (pine and the Gymnosperms generally).

579. **The cone** (**syncarpium**, *συν*, together) of the Magnolia tribe

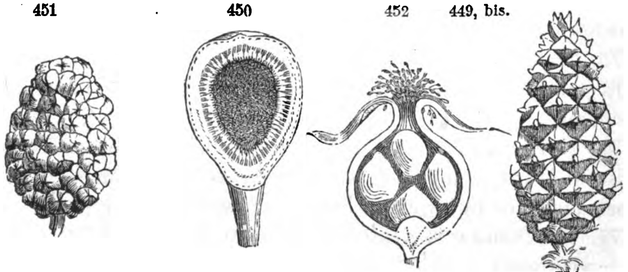


Fruits. 441, Etærio of Rubus strigosus (Blackberry). 442, Pepo; section of cucumber. 449, Berry, Grape. 443, Pome, Cratægus (Haw). 444, Pyxis of Jeffersonia. 445, Legume of Pea. 446, Loment of Desmodium. 447, Silique of Sinapis. 448, Silicle of Capsella.

is a mass of confluent, closed pericarps on a lengthened torus (cucumber tree).

580. THE FIG (syconus) is an aggregate fruit, consisting of numerous seed-like pericarps inclosed within a hollow, fleshy receptacle where the flowers were attached.

581. OTHER CONFLUENT FRUITS (SOROSIS) consist of the entire inflorescence developed into a mass of united pericarps, as in the mulberry, osage-orange, pine-apple.



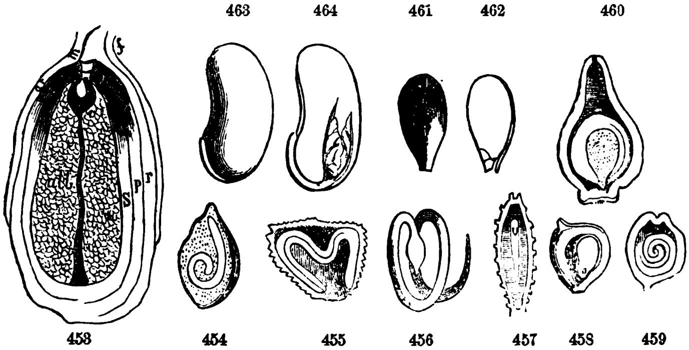
449, bis, Strobile of Pinus. 450, The Fig (syconus). 451, Sorosis of Mulberry. 452, Hip of Rosa, achmia nearly inclosed in the leathery calyx tube.

CHAPTER XIV.

THE SEED.

582. **The seed** is the perfected ovule, having an embryo formed within, which is the rudiment of a new plant similar in all respects to the original. The seed consists of a *nucleus* or kernel invested with

583. **The integuments or coverings.** The outer covering is the *testa*, the inner the *tegmen*, as in the ovule. The latter is thin and delicate, often indistinguishable from the testa.



Seed of Water-Lily (Nymphæa), enlarged section; *alb.*, albumen; *a*, the embryo contained in the embryo-sac; *s*, secundine or tegmen; *p*, primine or testa; *r*, raphe, *ar*, aril; *m*, micropyle; *f*, funiculus. 463, Seed of Bean. 464, Same, one cotyledon with the leafy embryo. 461, Seed of Apple. 462, One cotyledon showing the raphe and embryo. 460, Fruit of Mirabilis; embryo coiled into a ring. 454, Onion; embryo coiled. 455, Convolvulus; leafy embryo folded. 456, Embryo of Cuscuta. 457, Typha. 458, Ranunculus. 459, Hop.

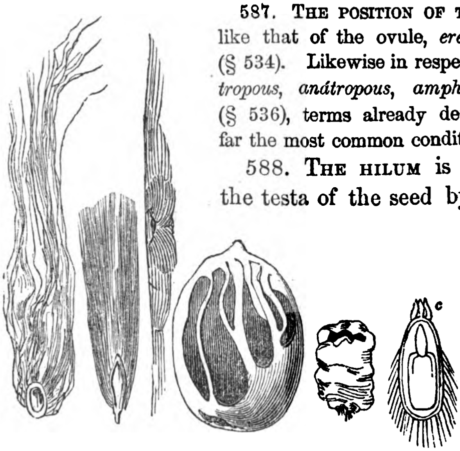
584. **The testa** is either membranous (papery), coriaceous (leathery), crustaceous (horny), bony, woody, or fleshy. Its surface is generally smooth, etc. (118, *a*).

585. **The coma must not be confounded with** the pappus, which is a modification of the calyx, appended to the pericarp, and not to the seed, as in the achenia of the thistle, dandelion, and other Compositæ. Its intention in the economy of the plant cannot be mistaken, serving like the pappus to secure the dispersion of the seed, while incidently as it were, in the case of the cotton-seed, it furnishes clothing and employment to a large portion of the human race.

586. **The aril** is an occasional appendage, partially or wholly investing the seed. It originates after fertilization, at or near the hilum, where the seed is attached to its stalk (funiculus). Fine examples are seen in the gashed covering of the nutmeg, called mace, and in the scarlet coat of the seed of staff-tree. In the seed of Polygala, etc., it is but a small scale, entire or 2-cleft, called *caruncle*.

587. **The position of the seed** in the pericarp is, like that of the ovule, *erect*, *ascending*, *pendulous*, etc. (§ 534). Likewise in respect to its inversions, it is *orthótropous*, *anátropous*, *amphítropous*, and *campylótropous* (§ 536), terms already defined. The anátropous is by far the most common condition.

588. **The hilum** is the scar or mark left in the testa of the seed by its separation from the funiculus. It is commonly called the *eye*, as in the bean. In orthótropous and campylótropous seeds, the hilum corresponds with the chalaza (§535). In other conditions it does not, and the raphe (§537) extends between the two points, as in the ovules.



465 464 463 461 460 462

460, Aril of Euonymus. 461, Aril of Nutmeg (mace). 462, Seed of Polygala, embryo, caruncle, c, (too small.) 463, Seed of Catalpa. 464, Seed of Willow. 465, Seed of Cotton.

589. **The seed kernel may consist of** two parts, the embryo and albumen, or of the embryo only. In the former case the seeds are *albuminous*, in the latter, *exalbuminous*, a distinction of great importance in systematic botany.

590. **The albumen** is a starchy or farinaceous substance accompanying the embryo and serving as its first nourishment in germination. Its qualities are wholesome and nutritious, even in poisonous plants. Its quantity when compared with the embryo varies in every possible degree; being excessive (Ranunculaceæ), or about equal (Violaceæ), or scanty (Convolvulaceæ), or none at all (Leguminosæ). In texture it is mealy in wheat, mucilaginous in mallows, oily in Ricinus, horny in coffee, ruminated in nutmeg and pawpaw, ivory-like in the ivory-palm (Phytelephas), fibrous in cocoa-nut, where it is also hollow, enclosing the milk.

591. **The embryo** is an organized body, the rudiment of the future plant, consisting of root (*radicle*), stem-bud (*plumule*), and leaves (*cotyledons*). But these parts are sometimes quite undistinguishable until germination, as in the Orchis tribe.

592. **The radicle** is the descending part of the embryo, almost always directed towards the micropyle, the true axis of the seed.

593. **The plumule** is the rudimentary ascending axis, the terminal bud, located at the base of, or between

594. **The cotyledons.** These, the seed-lobes, are the bulky, farinaceous part of the embryo, destined to form the first or seminal leaves

of the young plant. The nutritive matter deposited in the seed for the early sustenance of the germinating embryo is found more abundant in the cotyledons in proportion as there is less of it in the albumen,—often wholly in the albumen (wheat), again all absorbed in the bulky cotyledons (squash).

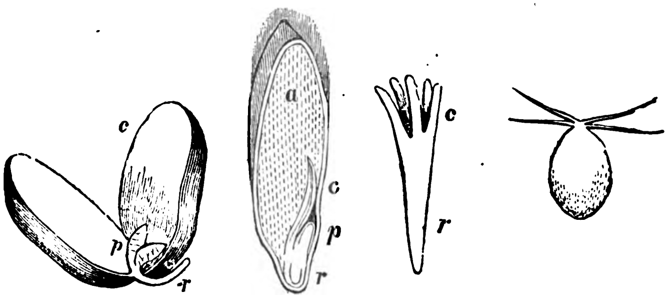
595. THE NUMBER OF THE COTYLEDONS is variable, and upon this circumstance is founded the most important subdivision of the Phænogamia, or Flowering-plants.

596. THE MONOCOTYLEDONS are plants bearing seeds with one cotyledon, or if two are present, one is minute or abortive. Such plants are also called *Endogens*, because their stems grow by internal accretions (§ 716). Such are the grasses, the palms, Liliaceæ, whose leaves are mostly constructed with parallel veins.

597. THE DICOTYLEDONS are plants bearing seeds with two cotyledons. These are also called *Exogens*, because their stems grow by external accretions, including the Bean tribe, Melon tribe, all our forest trees, etc. These are also distinguished at a glance by the structure of their leaves, which are net-veined (§ 258).

598. MORE THAN TWO COTYLEDONS. The Pine and Fir have seeds with several cotyledons, while the dodder is almost the only known example of an embryo with no cotyledon.

466 467 468 469



466, Dicotyledonous (Bean). 467, Monocotyledonous (Wheat). 468, Polycotyledonous (Pine). 469, Acotyledonous (zóospore of one of the Confervæ). (*r*, *r*, *r*, radicle; *p*, *p*, *p*, plumule; *c*, *c*, *c*, cotyledon; *a*, albumen).

599. THE POSITION OF THE EMBRYO, whether with or without albumen, is singularly varied and interesting to study. It may be *straight*, as in cat-tail, violet, or *curved* in various degrees (moon-seed, pink), or *coiled* (hop), or *rolled* (spice-bush), or *bent* angularly (buckwheat), or *folded* (Cruciferæ). In the last case three modes are to be specially noticed. 1, *Incumbent*, when the cotyledons fold over so as to bring the back of one against the radicle (shepherd's purse); 2, *accumbent*, when the edges touch the radicle (Arabis).

600. **The leafy nature** of the cotyledons is often distinctly manifest in their form and structure, as in Convolvulus (455).

A few plants, as the onion, orange, Coniferæ, occasionally have two or even several embryos in a seed, while all the Cryptogamia or flowerless plants have no embryo at all, nor even seeds, but are reproduced from *spores*, bodies analogous to the pollen grains of flowering plants (469).

OFFICE OF THE SEED.

601. **Its nature and use.** After the embryo has reached its wonted growth in the ripened seed, it becomes suddenly inactive and torpid, yet still *alive*. In this condition it is, in fact, *a living plant, safely packed and sealed up for transportation.* This is the distinctive and wonderful nature of the seed.

602. **Longevity of the seed.** This suspended vitality of the seed may endure for years, or even, in some species, for ages. The seeds of maize and rye have been known to grow when 30 to 40 years old; kidney-beans when 100; the raspberry after 1700 years (Lindley), and kernels of wheat found in a mummy-case, and therefore 3000 years old, were a few years ago successfully cultivated in Germany and England (Schleiden). Seeds of Mountain Potentilla (P. tridentata) were known to us to germinate at Meriden, N. H., after a slumber of 60 years. On the other hand the seeds of some species are short-lived, retaining vitality hardly a year (Coffee, Magnolia).

603. **In order that seeds may long retain their vitality** they must be kept dry. But an even temperature is by no means necessary, as they are generally able to resist all the changes of our climate from many degrees below zero to 110° above, provided no moisture is present.

604. **The dispersion of seeds** over wide, and often to distant regions is effected by special agencies, in which the highest intelligence and wisdom are clearly seen. Some seeds made buoyant by means of the coma, or pappus, already mentioned, are wafted afar by the winds, beyond rivers, lakes and seas; as the thistle, dandelion, silkgrass.

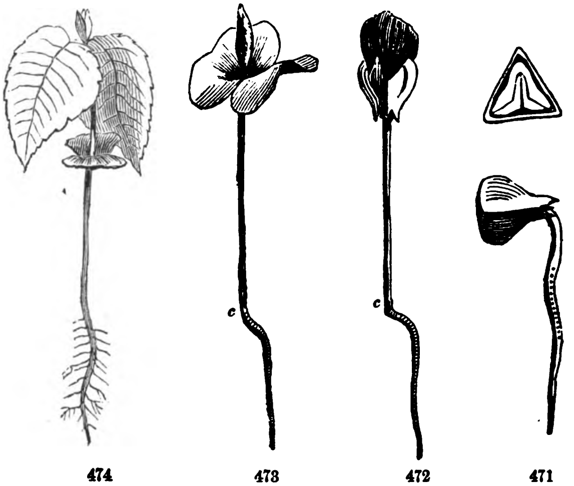
605. **Seeds are also furnished with wings** for the same purpose. Others are provided with hooks or barbs, by which they lay hold of men and animals, and are thus, by unwilling agents, scattered far and wide (burr-seed, tick-seed).

606. **Other seeds**, destitute of all such appendages, are thrown to a distance by the sudden coiling of the elastic carpels (touch-me-not). The squirting cucumber becomes distended with water by absorption, and at length, when ripe, bursts an aperture at base and projects the mingled seeds and water with amazing force.

607. **Transportation.** Rivers, streams, and ocean currents are all means of transporting seeds from country to country. Thus the cocoa and the cashew-nut and the seeds of mahogany have been known to perform long voyages without injury to their vitality. Squirrels laying up their winter stores in the earth, birds migrating from clime to clime, and from island to island, in like manner conspire to effect the same important end.

GERMINATION.

608. Definition. The recommencement of growth in the seed is called *germination.* It is the awakening of the embryo from its torpor, and the beginning of development in its parts already formed, so as to become a plant like its parent.



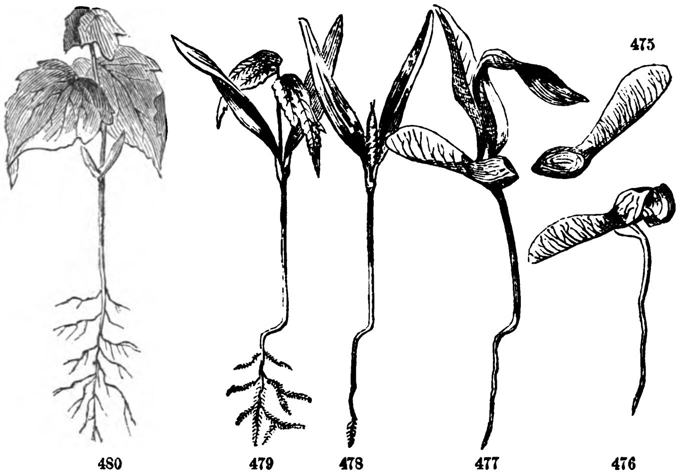
Germination of the Beach-nut. 470, Cross-section, showing the folded cotyledons. 471, The radicle only. 472, The ascending axis, above *c*, appears. 473, The cotyledons expand into the primordial leaves. 474, The first true leaves.

609. Experiment. All the stages of this interesting process may be conveniently observed, at any season, by an experiment. Let a few seeds, as of flax, cotton, wheat, pea, be enveloped in a lock of cotton resting upon water in a bulb-glass, and kept constantly at a proper temperature. Or, in spring, the garden soil will give us examples of all kinds everywhere.

610. That the seed may begin to grow, or germinate, it is first *planted*, or, at least, placed in contact with warm, moist soil. Concerning the proper depth of the planted seed agriculturalists are not agreed; but nature seems to indicate that no covering is needed beyond what will secure the requisite moisture and shade.

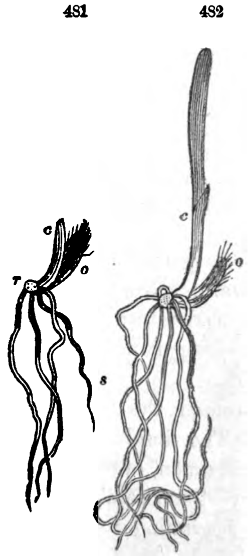
611. The process commenced. Thus situated the integuments gradually absorb water, soften and expand. The insoluble, starchy matter deposited in the cotyledons, or in the albumen, or in both, undergoes a certain chemical change, becoming sweet and soluble, capable of affording nourishment to the embryo now beginning to dilate and develop its parts. First (in the winged seed of the maple, scattered everywhere) the radicle is seen protruding from the micropyle, or the

bursting integument. A section of this seed would now show the folded embryo impatient of confinement.



Germination of the Maple. 475, Samara; section showing the folded cotyledons at *c*. 476—480, Progressive stages.

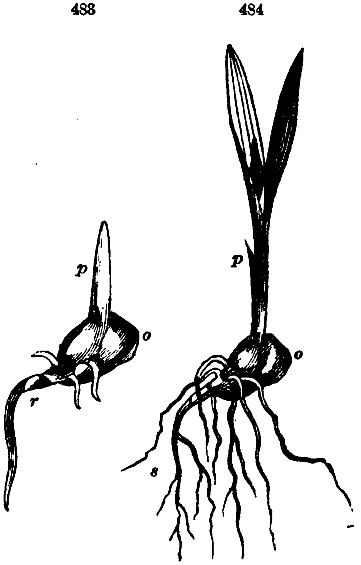
612. **The process concluded.** Soon the radicle has extended, and, pale in color, has hidden itself in the bosom of the dark, damp earth. Now the cotyledons, unfolding and gradually freed from the seed coats, display themselves at length as a pair of green leaves. Lastly the plumule appears in open air, a green bud, already showing a lengthening base, its first internode, and soon a pair of regular leaves, lobed as all maple leaves. The embryo is now an embryo no longer, but a growing plant descending by its lower axis, ascending and expanding by its upper.



Germination of Wheat; *o*, the grain containing the cotyledon; *c*, plumule; *r*, radicle; *s*, rootlets (adventitious).

613. **What becomes of the cotyledons.** The germination of the tulip-tree, oak, pea, squash, and other Dicotyledons may be watched with equal advantage, and the chief difference observed among them will be in the disposal of the cotyledons. In general, these arise with the ascending axis, as in the maple and bean, and act as the first pair of leaves; but sometimes, when they are very thick, as in the pea, buck-eye, oak (6—9), they remain as first placed with the collum (§ 118), neither ascending nor descending.

614. **The germination of monocotyledons**, as seen in Indian corn, wheat, tulip, is in this wise. The cotyledon is not disengaged from the seed, but remains stationary with it. The radicle (*r*) protrudes slightly and one or more rootlets (*s*) break out from it and descend. The plumule (*c*) shoots, at first parallel with the cotyledon along the face of the seed, but soon ascends, pushing out leaf from within leaf.



483, 484, Germination of Indian Corn.

615. **The conditions requisite** for germination are moisture, air, and warmth.

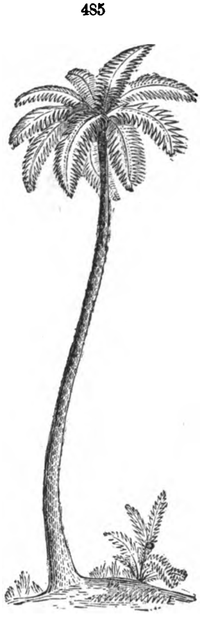
616. **Moisture** is necessary for softening the integuments, dissolving the nutritive matter, and facilitating its circulation. This is supplied in the rain and dew.

617. **Air**, or rather its oxygen, is required for the conversion of the starch into sugar—a process always depending upon oxydation. The oxygen absorbed unites with a portion of the carbon of the starch, producing heat, evolving carbonic acid, and thus converting the remainder into grape sugar, soluble and nutritive.

618. **Warmth** is a requisite condition of all vital action, as well in the *sprouting* of a seed as in the *hatching* of an egg. The proper degree of temperature for our own climate may be stated at 60° to 80°. Extremes of heat and of cold are not, however, fatal to all germination. In one of the Geysers of Iceland, which was hot enough to boil an egg in four minutes, a species of Chara was found in a growing and fruitful state. A hot spring in the island of Luzon, which raises the thermometer to 187°, has plants growing in it and on its borders. Many species of plants also seem well adapted to growth in the Arctic regions.

619. **Darkness** is favorable to germination, as proved by experiment, but not an indispensable condition. Hence, while the seed should be covered for the sake of the moisture and shade, the covering should be very thin and light, for the sake of a free access to air.

485



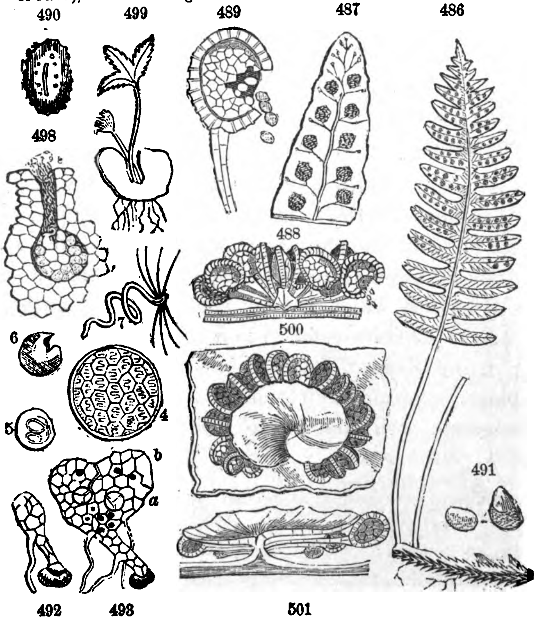
485, A Tree Fern (of the Island of Java), 40 feet in height.

620. **THE CAUSE OF THE DOWNWARD TENDENCY OF THE ROOT** is a theme of much discussion. Some have referred it to the principle of gravitation; others to its supposed aversion to light. But it is a simple and satisfactory explanation that its growth or cell-development takes place most readily on the moist side of its growing point, and consequently in a downward direction, so long as the soil in contact with its lower surface is more moist than that above. Hence also the well-known tendency of roots toward springs and water-courses.

CHAPTER XV.

THE CRYPTOGAMIA OR FLOWERLESS PLANTS.

621. **DISTINCTION OF PARTS.** In the lowest of the Cryptogamic tribes the organs of vegetation and of reproduction are the same. Each cell in the structure grows, nourishes, multiplies. Higher in the scale we find a gradual specialization of organs, and in the higher tribes, as in

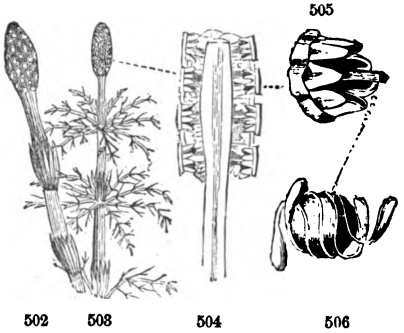


A Fern, Polypodium vulgare. 486, Its frond. 487, Lobe of the frond enlarged, showing the sori, 488, One of the sori (magnified) consisting of many sporangi. 489, One sporange (further magnified) bursting and discharging the spores. 490, A spore. 491, Spores beginning to germinate; and 492, 493, producing the *prothallus* with rootlets. At *a* appear the *antheridia* and at *b* the archegones on the surface of the prothallus. 494, Antheridium. 495, One of its cells. 496, The same burst; and 497, the spermatozoid escaped. These float about, and some of them at length enter, 498, the archegone, fertilizing, and at length producing, 499, the young Fern. 500, Sorus of Aspidium marginale, covered with the *indusium*. 501, Same, side view.

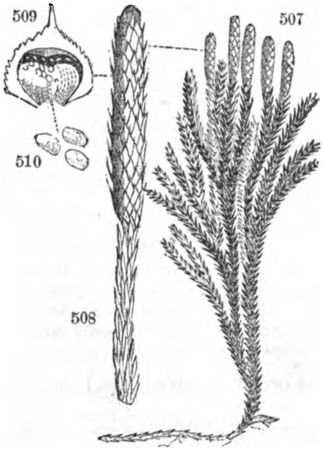
the Phænogamia, one portion is devoted to the preservation of the individual, the other to the preservation of the species; in other words, the organs of vegetation and of reproduction become separate and distinct.

622. DISTINGUISHED FROM PHÆNOGAMIA. But the reproductive organs, although distinct from the nutritive, are never seen combined into flowers, nor producing seeds marked by the presence of an embryo. Hence in the scale of rank the cryptogams are inferior to the flowering plants and easily distinguished from them.

623. VEGETATIVE ORGANS. Again in the lower tribes, viz., the seaweeds, Fungi and Lichens, there is no distinction of root, stem and leaves; but the entire plant grows into an expansion of substance more or less uniform and indefinite, called a thallus. But the higher Hepaticæ, mosses, club-mosses, Equisitaceæ, ferns and marsileads, possess stems, roots and leaves like the Phænogamia.



502, Equisetum arvense. 503, E. sylvaticum. 504. Section of the spike. 505, A sporange. 506, A spore with its elators coiled.



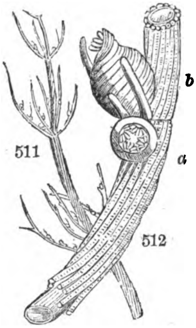
507, Lycopodium dendroideum. 508, A single spike. 509, a scale with its sporange bursting. 510, Spores.

624. CLASSES. The tribe last mentioned are embraced in the class Acrogens, so named by Lindley from their manner of growth (ἀκρόν, point or summit), lengthening into an axis. The remaining three tribes first named above constitute the lowest class of the vegetable kingdom, called Thallogens, and named from their manner of growth.

625. THE STEMS OF THE MARSILEADS and ferns are mostly rhizomes, but in tropical countries some species of the latter arise on firm ærial trunks like palms. The club-mosses have slender, woody stems much inclined to bifurcate. Those of the Equisetaceæ, Characeæ are jointed,

bearing slender, whorled, leafless branches. The mosses and Hepaticæ have filiform stems and branches, erect and creeping. Fern leaves and mushrooms arise on stipes.

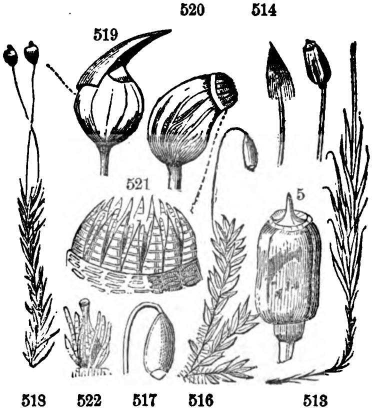
626. Leaves. The ferns are characterized by their great development of leaves called *fronds.* They are rarely simple, often pinnatifid, or pinnate, simply, doubly or triply. Their venation is fork-veined and their vernation circinate. The leaves of the mosses and Hepaticæ are veinless and delicate, mostly ovate and entire, numerously covering the axis. Those of the latter are often garnished with stipule-like processes called *amphigastria.*



511, Chara fœtida. 512, Portion of a branch; the two reproductive organs- *a*, Globule; *b*, nucule.

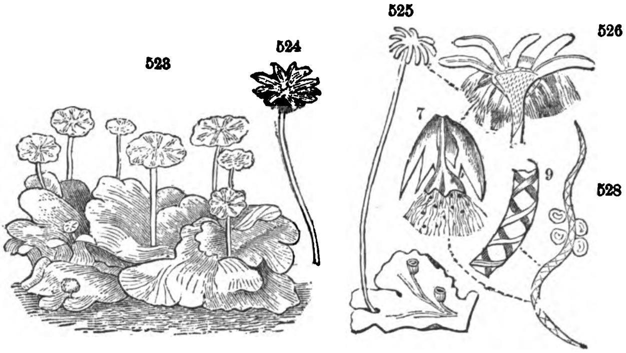
627. Thallus. The vegetative system of the Thallogens consists either of delicate filaments or of flattened membranes, varying in color through every shade and hue. In Marchantia, lichens, and seaweeds it is green, olive or red, and called thallus. It may resemble a leaf or a stem, but its functions are still the same. In size it varies from the microscopic Confervæ to the gigantic seawrack, a furlong in length. Its structure is purely cellular and uniform, or, as in Marchantia, in layers.

628. Mycelium or spawn is the vegetative system of the Fungi, distinguished from thalli by its want of coloring matter in its cells. It consists of meshes of white or colorless filaments, branching and anastamosing to form entangled masses pervading the substance in which the Fungus grows. It is far less conspicuous than the fructification (toad-stool, etc.) which ultimately arises from it.



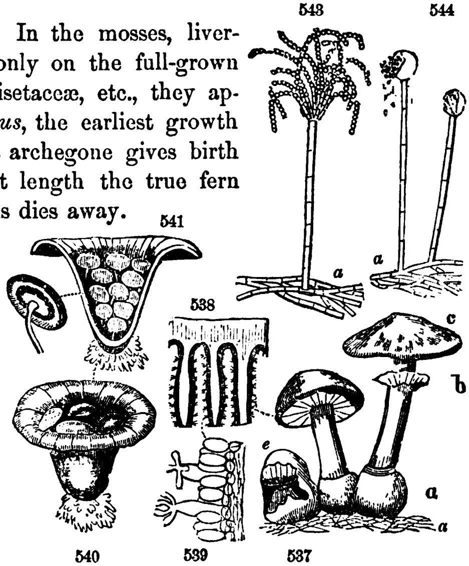
Mosses. 513, Polytrichium. 514, Sporange with calyptra, without calyptra. 515, Sporange (enlarged) with the operculum at top. 516, Mnium, 517, Sporange. 518, Bartramia. 519, Sporange with calyptra. 520, Same mature, open. 521, Peristome. with its teeth. 522, Antheridium and paraphases (a flower) of Polytrichium.

629. The reproductive organs of the Cryptogamia are the antheridia and archegonia; and by their reaction spores in various spore-vessels are produced. They have been detected in nearly all the cryptogamic tribes, and are supposed to represent the stamens and pistils



Hepaticæ. 523, Marchantia, sterile plant. 524—5, Fertile plant. 526, Vertical section of the fertil-receptacle; 527, of a perianth, showing the sporange bursting. 528, One of the elators with four spores. 529, Portion of it highly magnified.

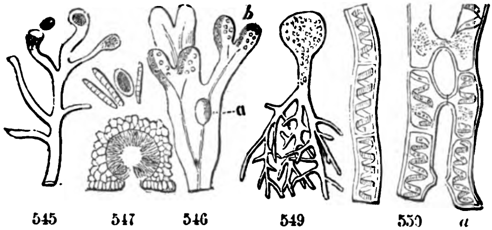
of the flowering plants. In the mosses, liverworts, etc., they appear only on the full-grown plant; in the ferns, Equisetaceæ, etc., they appear only on the *prothallus*, the earliest growth of the spore, and here the archegone gives birth to an embryo, whence at length the true fern arises, while the prothallus dies away.



Fungi. 537, Agaricus (Mushroom) in various stages: e, tearing open the volva; b, annulus, the remains of the veil (e); c, pileus; a, mycelium. 538, Portion of the gills. 539, Basidia and spores from the same (magn. 400 diam.). 540, Cyathus; 541, Section. 542, One of the conceptacles. 543, Penicillium (mildew). 544, Mucor; a, mycelium.

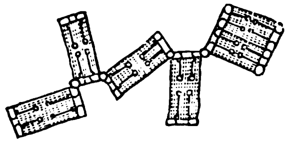
630. Spores. These are the true reproductive germinating bodies of the Cryptogams. They consist each of a single cell, often exceedingly minute, and produced in immense numbers. The cell-wall of the spore may be simple (Botrytis) or double, as if a cell within a cell (ferns). But the spores are often apparently double or 2-celled (lichens), or 4-celled, or 6, 8, or many-celled. These compound spores are in fact spore-vessels inclosing several spores yet immature, and called sporidia or theca-spores. The spores or sporidia are often inclosed in still larger cells called the sac.

631. Endospores and exospores. Spores are developed either in the interior of the parent cell or on the outside of it, and hence the di-



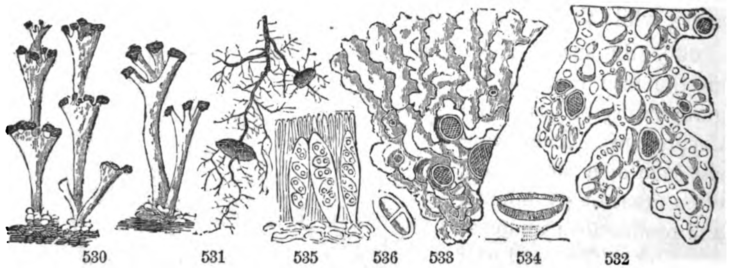
Seaweeds (Algæ). 545, Vaucheria forming and discharging its spores (*a*) at the extremities. 546, Fucus; *a*, air-vessel; *b*, fruit, a mass of conceptacles. 547, Transverse section of a conceptacle. 548, A spore with paraphases. 549, Hydrogastrum, consisting of a single cell. 550, Spirogyræ (Frogspittle) one of the Confervæ; *a*, two threads (thalli) conjugated, *i. e.*, united by tubes.

division of the Cryptogams into the Enpores and the Exospores. In the latter case the parent-cells are called *basidia*, and many such united, as in the lichens' and mushrooms, form a tissue called hymenium. In lichens such sporiferous tissues existing in spots of definite form, constitute the *apothecia* when flat, *receptacles* when concave, and *conceptacles* when hollow.



551, Frustules of a Diatomaceous Alga (Diatoma marinum) separating from each other.

632. THE THECÆ OR SPORANGIA of ferns and mosses consist of tissues rather than of single cells, and contain numerous spores. In ferns they grow on the back of the fronds in little clusters called *sori*. When mature, the sporange is torn open by the contraction of an elastic ring which surrounds it. In the mosses the sporange is stalked, solitary, terminal, and opens by a definite number of teeth called the *peristome*.



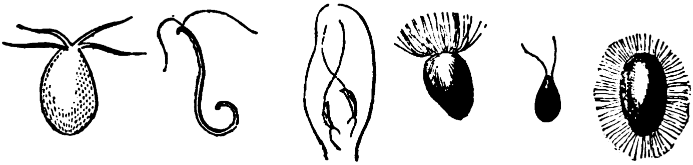
Lichens, 530, Cladonia; the minute thallus at the base of the podetia, cup-like above, bearing scarlet conceptacles. 531, Usnea. 532, Sticta. 533, Parmelia. 534, Receptacle, vertical section. 535, A portion (highly magnified) with thecæ and paraphases. 536, A spore (double).

633. ZOOSPORES AND SPERMATOZOIDS are minute bodies endowed with spontaneous locomotion in water by means of vibratile ciliæ. Zoöspores of ovate form proceed from the vegetative cells of the Algæ, swim about for a time, then settle down and grow into new plants. Spermatozoids are mostly filiform bodies with several ciliæ, discharged from the

antheridia (as pollen ?) and actively floating until they reach the archegones, or perish.

634. Alternate generation is a phenomenon distinctly traced in many of the cryptogams. Thus the mosses, in germinating, first produce long, greenish filaments quite analogous to the Confervæ (frog's-spawn). From these, at length, buds arise and grow into a true moss. Ferns, also, and Equisetaceæ, first from the spore exist in the form of a liverwort—a small green thallus, creeping and rooting along the ground. Secondly, upon this *prothallus* reproductive organs are developed and an embryo, whence a true fern arises. Thus the plant is transiently, as it were, a liverwort, permanently, a fern. (§21—23.)

635. Other modes of propagation occur in these plants, as, for example, by *innovations*, *sporules*, *gonidia*. These bodies are analogous to bulbs and bulblets in the flowering plants, originating from the nutritive organs, and capable of separating from the parent and growing up independent plants.



552, Zoöspore of one of the Confervæ (Chaetophora). 553, Phytozoön of Chara. 554, Antheridium of Fucus containing two phytozoa. 555, Zoöspore of Confervæ with a tuft of ciliæ. 556, Another species with but two ciliæ. 557 Zoöspore of Vaucheria with ciliæ all around.

PART SECOND.

PHYSIOLOGICAL BOTANY.

CHAPTER I.

OF THE VEGETABLE CELL.

636. **Revelations of the microscope.** We have now completed a brief survey of the phenomena of visible vegetation. We commenced with the root and now the consideration of the seed with its embryo completes the circle and brings us around to the root again. We have studied hitherto superficially, as best we were able by the unassisted eye. But the microscope opens to us a new world in botany, more wonderful and fair, if possible, than that which we have already surveyed. No just appreciation of microscopic botany can be obtained from drawings or descriptions. Here the microscope itself is the only adequate teacher.

637. **Next inquiries.** We have seen and studied the general organs of vegetation and their metamorphoses; but of what are these organs made? What their structure *within?* What their office and use in the life and growth of the plant? These inquiries must next be answered.

638. **Structure of plants cellular.** All forms of vegetable structure, however numerous and diverse, are alike composed of little bladders, called *vescicles* or *cells.* We can often discern the cells in some structures with the naked eye, as in the pith of elder, pulp of snowberry, and especially plain in the pulp of orange. Other structures, which appear as a solid mass to the eye, are seen at once, under the lens, to consist of cells also—even the most solid wood or the stony substance of the peach. A thin cutting (shaving) from the rhizome of the blood-root, magnified 100 diameters, appears in outline (to say nothing of its brilliant coloring) as here sketched (557). Therefore

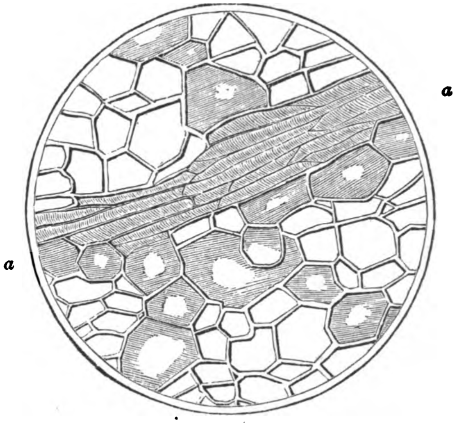
639. **The cell** is the elementary organism which by its repetitions makes up the mass of all vegetation. It is defined as a *closed sac composed of membrane containing a fluid.*

640. **The primary form of the cell** is spheroidal. In some cases it retains this form during its existence, but generally, in growing, it takes new and various forms, which, on account of the two causes which control them, may be classed as *inherent* and *casual.*

641. **The inherent forms of the cell,** or those which depend upon its own laws of growth, may be referred to three general types;

(1) *spheroidal*, like pollen grains, the red snow-plant, the cells of leaf-tissue, etc., varying to oblong, or lobed, or stellate ; (2) *cylindrical*, or tube-form, as most wood-cells are ; (3) *tabular* or flattened, as the cells of the epidermis.

642. THE CASUAL FORMS result from external pressure, as of cells crowding against cells, in stems or pith. In this way spheroidal cells may become cubical, 8-sided, 12-sided, etc ; tubiform cells prismatic, and tabular cells 4-angled, hexagonal, etc., in outline according to the original pattern.



557, Section of the rhizome of Blood-root. *a*, *a*. A bundle of wood-cells. The shaded cells contain the color.

643. IN MAGNITUDE the plant cell varies from $\frac{1}{100}$ to $\frac{1}{300}$ of an inch in diameter; the more common size is about $\frac{1}{300}$ inch. The cells of elder pith measure about $\frac{1}{200}$ inch; those of parenchyma (leaf-tissue) about $\frac{1}{400}$; consequently, 64,000,000 of them would occupy only one cubic inch. The cells of cork are computed to be $\frac{1}{1000}$ inch in diameter—1000 millions to a cubic inch.

644. BUT THE LENGTH of some cells is much more considerable. Wood-cells measure $\frac{1}{50}$ inch; bark cells, as flax, hemp, nearly $\frac{1}{2}$ inch; the cells of some plant-hairs an inch or more.

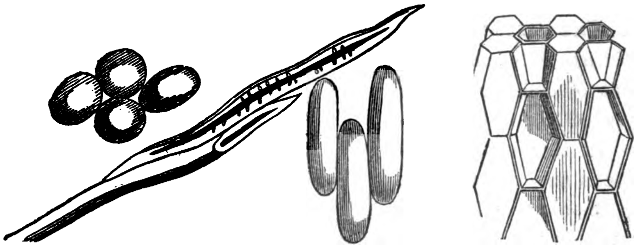
645. THE WALL of the new cell consists of two layers; the outer one a firm, colorless membrane, made of *cellulose*, the inner a plastic, gelatinous layer applied to the outer, and chiefly concerned in cell-life and multiplication. This is called the *primordial utricle*.

646. IT IS BEST SEEN WHEN treated with a weak solution of nitric acid, iodine, or alcohol. It thus becomes colored, contracts, and lies loose in the cell.

647. THE CELL WALL IS EASILY PERMEATED by fluids flowing in and out. It must, therefore, be regarded as porous; although it appears perfectly entire even under the highest magnifier.

648. A SECONDARY LAYER is subsequently added to the outer layer, between it and the primordial utricle, as if to strengthen it. This new layer is seldom entire, but perforated and cleft in a great variety of patterns, leaving certain points or parts of the cell-wall still bare and discernible by their transparency. Hence the following varieties of cells:—

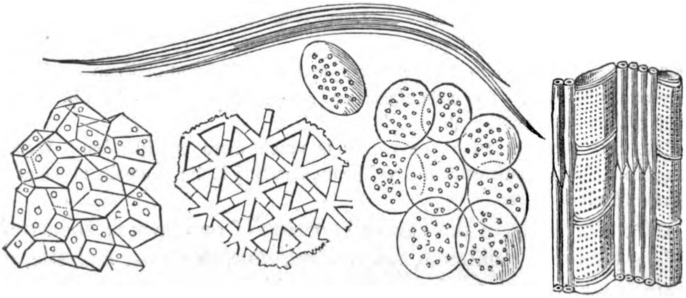
649. **Wood cells**, which are finally filled up by the repetitions of the secondary layers, leaving only minute points of the original cell-wall bare and transparent.



Forms of cells. 560, Wood-cells. 561, Cellular tissue of a rootlet, etc.

650. **Pitted cells**, a variety where larger transparent points appear, surrounded by 2 or 3 rings (pine and the Coniferæ in general).

651. **Spiral cells**, where the secondary layer consists of spiral fibers or bands. There may be a single fiber, or several (2 to 20) united into a band. It is usually elastic and may be drawn out and uncoiled.



562, Polyhedral cells of parenchyma in pith of Elder. 563, Stellate cells in pith of Rush. 565, Spherical cells in Houseleek. 566, Wood-cells and ducts of Oak. 564, Wood-cells of the Flax-fiber.

These beautiful cells may be well seen in a shoot of elder, in the petiole of rhubarb, Geranium, strawberry. In the two latter, if gently pulled asunder, the coiled fibers appear to the naked eye.

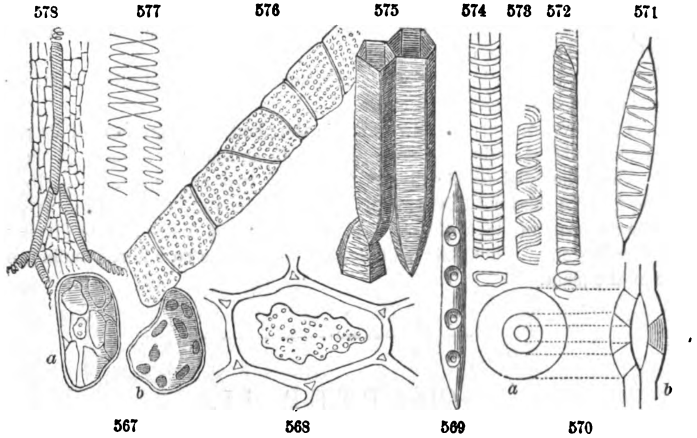
652. **Annular cells**, when there are numerous rings within, instead of a spiral coil, as in the stems of balsam and some Cryptogamia.

653. **Scalariform cells**, when the rings seem conjoined by bars crossing between them, giving an appearance compared to a ladder (*scala*), as in the vine and ferns. *Porous* cells with the secondary layers full of perforations, *reticulated* cells, as if a net-work; and many other forms.

654. **Cellulose**, the material of which the outer cell-walls and other secondary layers are made, is proved by a chemical analysis to consist of three simple elements, carbon, hydrogen, oxygen, in the proportions of C_{24} H_{20} O_{20},—carbon and the exact elements of water. In the material of the primordial utricle nitrogen is added. Out of these four simple elements (C H O N) with slight additions of lime, silex, and a few other earthy matters, God is able to produce all the countless varieties of plants which clothe and beautify the earth.

655. **Contents of the cell.** Some cells contain air only. Others are filled with solid matter; but the greater part contain both fluids and solids. There is the *cytoblast*, a globular atom, earliest of new cells; and *protoplasm*, the nourishing semi-fluid, both of the same material as the primordial utricle, and with it, and the fluid cell-sap, ever flowing, acting, combining, transforming, and producing either new cells or products like the following.

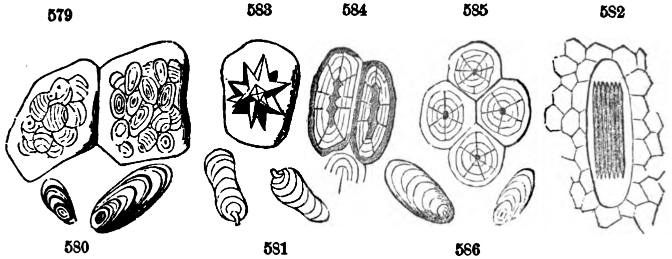
656. **The coloring matter**, which gives to fruits and flowers their bright and varying tints of yellow, red, and blue, is generally dissolved in the cell-sap which is otherwise colorless; but



567, Cells, *a*, of the pulp of Snow-berry, showing the nucleus; *b*, of the parenchyma of the leaf of Pink, showing the granules of chlorophylle. 568, Cell of a Cactus, soaked in Alcohol, the primordial utricle separated and contracted. 569, Cell of pleurenchyma of Pine, dotted. 570, Sketch to illustrate the nature of those dots; *a*, dot seen in front; *b*, a side view of the same. 571, Trachenchyma, a spiral cell from the sporange of Equisetum. 572, Spiral vessel of the Melon, single thread; 573, of the Elder, 4 threads. 574, Annular duct, distended by rings instead of a coil. 575, Scalariform vessels, from Osmunda (Fern). 576, A dotted duct from Gymnocladus (Coffee-tree). 578. Spiral vessels apparently branched. 577, Branching spirals in the Gourd.

657. **Chlorophylle**, the green coloring matter of leaves, consists of green *corpuscles* floating in the colorless sap or attached to the colorless wall. In the indigo plant these corpuscles are blue and constitute that poisonous drug.

658. **The starch** of the plant also originates here, in the form of little striated granules of the same composition as cellulose ($C_{24}H_{20}O_{20}$). Some 20 such granules appear in the same cell, either loosely or compactly filling it. Starch is nutritive matter, sealed up for preservation and future use.



Contents of cells. 579, Cells of Potato containing starch grains. 580, Starch grains from the potato; 581, from the E. Indian Arrow-root. 582, Raphides, acicular crystals, in a cell of Polyanthes tuberosæ. 583, Crystals in a cell of Cactus. 584, Cells from the pulp of Pear, coated internally; a longitudinal section; 585, Transverse section. 586, Starch granules from W. Indian Arrow-root.

659. **Gum, sugar, salts,** acids, alkalies, poisons, medicines, whatever is peculiar in the properties of each vegetable substance, may also be held in solution in the cell-sap and invisible, unless forming

660. **Raphides,** little bundles of crystals, acicular or of some other form, seen in the cells of rhubarb, Cactus, Hyacinth.

661. **The development of new cells** in the plant is the process of its growth. This is accomplished within the pre-existing cells and by the agency of their contents. The primordial utricle divides itself into two or more utricles, by septa growing from its sides until they meet. These then acquire the cellulose layer outside, the cytoblast inside, at the expense of the old cell, which shortly gives place to its new progeny. Thus cells multiply, and by millions on millions build up the fabric of the plant.

CHAPTER II.

THE TISSUES.

662. **One-celled plants.** The cell, as heretofore described, is endowed with a life within itself. It can imbibe fluids, nourish itself, and reproduce others like itself. It may, therefore, and actually does in some cases, exist alone as a plant! Many species of the Confervoids and Diatomes are plants consisting of a single cell—the simplest possible form of vegetation.

663. **Plants many-celled.** With a few such exceptions, vegetation consists of a combination of cells united in a definite manner and form.

Such combinations are called *tissues*, which we may describe under four general names or types:

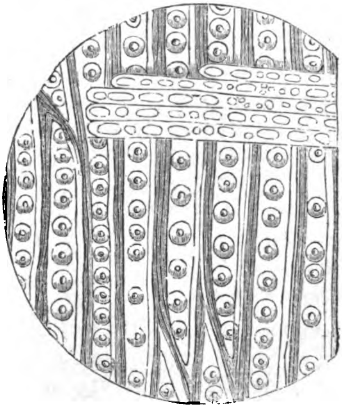
I. CELLULAR TISSUE (PARENCHYMA):
II. FIBROUS TISSUE (PLEURENCHYMA):
III. VASCULAR TISSUE (TRACHENCHYMA):
IV. LATICIFEROUS TISSUE (CIENCHYMA).

664. PARENCHYMA, composed of spheroidal cells, is the most common form of tissue, no plant being without it, and many, especially of the lower orders, being entirely composed of it. Numerous varieties occur according to the forms of the cells and their closeness of contact, intermediate between the following extremes, 1, when there are copious intercellular spaces, the cells slightly touching, and being (*a*) rounded, or (*b*) lobed, or (*c*) stellate; 2, when the cells are crowded, leaving no intercellular space and being (*d*) prismatic, or (*e*) polyhedral, or (*f*) irregular.

665. EXAMPLES of these tissues are found (*a*) in the pulp of fruits, in newly-formed pith, and in all young growths; (*b*) in the lower stratum of leaf-tissue; (*c*) in the pith of rushes and other aquatic plants; (*d*) in the herbaceous stems of Monocotyledons; (*e*) everywhere, but well observed in full-formed pith; (*f*) abundant in all the soft, fleshy parts of plants.

666. PLEURENCHYMA is composed of elongated cells cohering by their sides in such a way that end overreaches end, forming a continuous *fibre.* Two varieties are noticed (*a*) *wood-fibre*, with cells of moderate length, remarkable for its firmness, the main constituent of the stems and trunks of the higher plants; (*b*) *liber*, with very long attenuated cells, the substance of the inner layers of bark, remarkable for its tenacity, especially in flax, hemp, linden.

667. THE PITTED CELLS (§ 650) constitute a singular variety of wood-fiber, common in pines, firs, etc. That mysterious double ring which encircles each pit, is projected, the inner by the pit itself, which is an aperture in the secondary layer, the outer by a lens-shaped intercellular cavity right opposite outside. (470).



579, Longitudinal section of Thuja (Red Cedar). *a*, Medullary rays.

668. TRACHENCHYMA is a tissue of *vessels* or tubes rather than cells. The vessels are extended lengthwise, and composed each of a row of cells joined end to end, and fused into one by the absorption of the

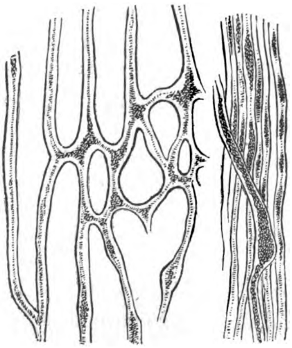
contiguous walls. This tissue varies according to the character of the constituent cells, which are (*a*) spiral, or (*b*) annular, or (*c*) sclariform, or (*d*) reticulated.

669. Such cells, with their tapering ends, form vessels with oblique joints. When porous cells (653) with their truncated ends unite they form right-jointed vessels resembling strings of beads, called *dotted* or *vascular ducts*. These are usually quite large, and characteristic of the woody layers of all exogenous plants. (470.)

670. THE DIFFERENT VARIETIES OF TRACHENCHYMA are assigned to different regions and offices, (*a*) to the earliest formed part of the wood, the petioles and veins of leaves, petals of flowers, etc.; (*b*) to similar parts, but later formed, most abundant in ferns and Equisetaceæ; (*c*) in the woody bundles of the Endogens and in the succulent parts of plants in general; (*d*) most abundant in ferns, club-mosses.

671. CIENCHYMA is a system of milk-vessels—vessels secreting the latex or peculiar juice of the plant, white, yellow, red, turbid, containing opium, gamboge, caoutchouc, resin, etc. It occurs in the petioles and veins; in the parenchyma of roots, in the liber especially; sometimes simple, generally branched and netted in a complicated manner, as well seen in the poppy, celandine, blood-root, gum-elastic tree, etc.

580



581

Vessels of Cienchyma ; 580, from Dandelion; 581, from the Celandine.

672. THEIR NATURE. These vessels are probably mere open spaces between the cells at first, subsequently acquiring a lining membrane which never exhibits pores or spiral markings. But there are also true

673. INTERCELLULAR PASSAGES filled with air and admitting its free circulation in all directions through the parenchyma. These are necessarily very irregular, and they communicate with the external air through the stomata. (§ 678.)

674. IMPORT OF THE CELL. Thus the cell appears to be the type of every form of tissue, the *material* of which the vegetable fabric is built, and the *laboratory* where the work is performed.

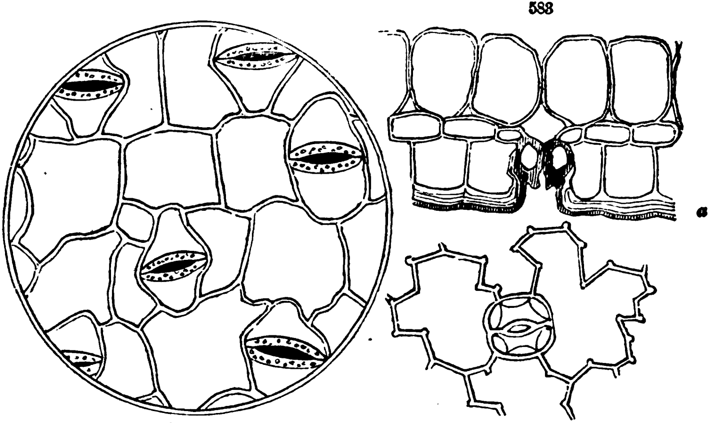
675. ELEVATION IN RANK IS MARKED BY the increasing complication of the tissues. The basis of the structure of all plants is parenchyma. In the lowest tribes no other tissue is ever added, this alone performing all the functions. Higher in the scale, as in mosses, a few central bundles of wood tissue are added, as if to strengthen the stem. Still higher, as in ferns, etc., we begin to find vessels (trachenchyma) of the simpler sort, for the freer circulation of the fluids, together with the strengthening pleurenchyma. Lastly, in the highest plants, Phænogamia, the true spiral vessels appear, filled with air, cienchyma with secretions, and all the tissues in their appropriate functions.

CHAPTER III.

THE EPIDERMAL SYSTEM

INCLUDES the external covering of all herbaceous growths, viz., the epidermis, stomata, hairs, glands, cuticle, etc., organs which in older stems give place to bark.

676. THE EPIDERMIS (skin) consists of a layer of united, empty cells, mostly tabular, forming a superficial membrane. It invests all plants higher than mosses, and all parts save the extremities, the stigma and rootlets. Its office is to check evaporation.

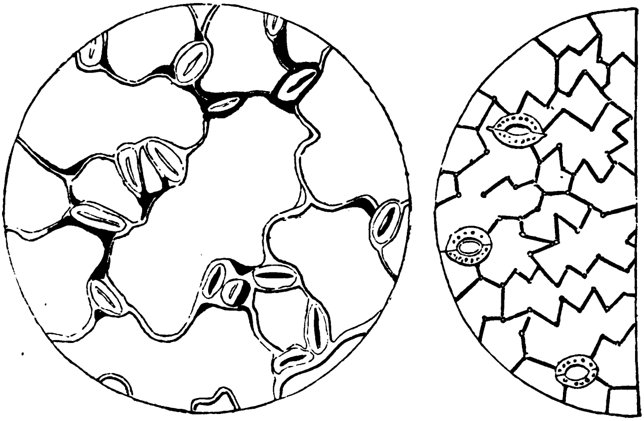


582, Cells of epidermis with a stoma from leaf of Helleborus fœtidus. 583, Vertical section of a stoma of Narcissus; *a*, cuticle. 584, Epidermis cells with stomata of Tradescantia Virginica.

677. EXAMPLE. That delicate membrane which may be easily stripped off from the leaf of the houseleek or the garden iris is the epidermis. It is transparent, colorless, and under the microscope reveals its cellular structure.

678. STOMATA. The epidermis does not entirely exclude the tissues beneath it from the external air, but is cleft here and there by little chinks called *stomata* (mouths). Each stoma is guarded by a pair of reniform cells, of such mechanism (not well understood) as to open in a moist atmosphere and close in a dry.

679. POSITION OF STOMATA. The stomata are always placed over and communicate with the intercellular passages. They are found only on the green surfaces of parts exposed to the air, most abundant on the under surface of the leaves. Their numbers are immense. On the leaf of garden rhubarb 5,000 were counted in the space of a square inch; in the garden iris, 12,000; in the pink, 36,000; in Hydrangea, 160,000.



585, Cells and stomata of the epidermis of Oxalis violacea; and 586, of Convallaria racemosa.

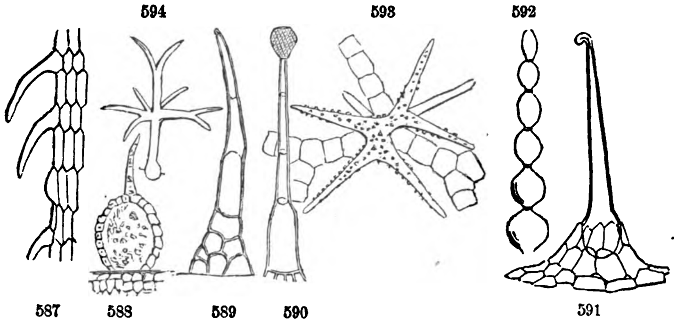
680. **Cuticle.** The surface of the epidermis at length becomes itself coated with a delicate, transparent pellicle, not cellular, called the *cuticle.* It varies in consistency, being thicker and stronger in evergreen and succulent plants. It seems to be merely the outer cell wall of the epidermis thickened and separated from the newly-formed wall beneath it.

681. **The hairs** which clothe the epidermis are mere expansions of its tissue. They may each consist of a single elongated cell, or of a row of cells. They may also be simple, or branched, or stellate, or otherwise diversified.

682. **Glands** are cellular structures serving to elaborate and contain the peculiar secretions of the plant, such as aromatic oils, resins, honey, poisons, etc. A gland may be merely an expanded cell at the summit of a hair, or at its base, and hence called a *glandular hair* (Labiatæ). Or it may be a peculiar cell under the epidermis, giving to the organ a *punctate* appearance, as in the leaf of lemon. Other glands are *compound* and either external (sundew), or internal reservoirs of secretion (rind of orange).

683. **Stings** are stiff-pointed, 1-celled hairs expanded at base into a gland containing poisonous secretion. An elastic ring of epidermal cells presses upon the gland so as to inject the poison into the wound made by its broken point (nettle).

684. **Prickles** are hardened hairs connected with the epidermis alone, thus differing from spines, which have a deeper origin. Examples in the rose.



587, Rootlet of Madder, showing cells expanded into fibrillæ. 588, Glandular hair of Fraxinella, section. 589, Hair of Bryonia, of several cells. 590, Hair of several cells, surmounted by a gland, of Antirrhinum majus. 591, Sting of Urtica dioica. 592, Jointed hair of the stamens of Tradescantia. 593, Stellate hair from the petiole of Nuphar advena (magnified 200 diameters, Henfrey). 594, Branched hair, one cell, of Arabis.

CHAPTER IV.

THE LIGNEOUS SYSTEM

685. Includes the firm structures of roots, stems, and their appendages, summarily called *the wood.*

686. Structure. The growing rootlet of the germinating plant exhibits under a microscope a nearly uniform mass of cellular tissue. The cells composing it are soft and delicate, with thin, porous walls adapted to absorb moisture, which it has already begun to do. It grows by the accession of cell to cell through their division and enlargement at its point, or rather just behind the advance layer which constitutes its cap (pileorhiza § 725.

687. The earliest tissue. The same structure also appears in the expanding cotyledons and the opening bud of the plumule. At this early stage, therefore, all plants alike in all their parts are composed of simple parenchyma. Subsequent changes in structure occur, giving to each tribe its several peculiarities. Still the growing points of the axis, both ascending and descending, advance by the formation of the same tissue, and the *vessels*, if formed at all, follow a little later.

688. The changes. The rootlet soon becomes a *root*, assumes a corky layer instead of the tender, spongiform epidermis, and ceases to absorb. But new rootlets spring from the radicle, or branch from the axis, which in their turn absorb, harden, divide and subdivide; and so on indefinitely.

689. The increasing demand for moisture is thus met by the multiplication of these root ends, which have been called the *spongelets*. The absorbing surface is also greatly increased by the hair-like processes of the epidermis;—the fibrillæ (§ 724) which multiply generally in proportion to the dryness of the soil.

690. There are four general modes of growth and structure, whereby the vegetable kingdom is distinguished into as many great classes, viz.:

THE OUTSIDE-GROWERS (EXOGENS),
THE INSIDE-GROWERS (ENDOGENS),
THE POINT-GROWERS (ACROGENS),
THE MASS-GROWERS (THALLOGENS).

691. THE EXOGENOUS STRUCTURE. A cross section of the stem or branch of any dicotyledonous plant (mustard, maple), exhibits zones of different structures, which are distinguished as pith, medullary sheath, wood, and bark.

692. THE PITH occupies the central part of the stem. It consists of parenchyma, is chiefly abundant in herbaceous plants and all young stems. When new, it is filled with fluids for the nourishment of the buds until they can make food for themselves. As the plant advances in age, the pith loses its vitality, is filled with air only, is often torn into irregular cavities, or disappears.

693. THE MEDULLARY SHEATH immediately surrounds the pith. It is a thin, delicate tissue consisting of spiral vessels. It communicates with every bud, and sends off detachments of its vessels to the petioles and veins of every leaf. Its tubes secrete oxygen from carbonic acid or water and convey it to the leaves.

694. THE WOOD consists of pleurenchyma and ducts (§ 666) arranged more or less distinctly in concentric zones or layers. The first or inner layer, together with the medullary sheath and pith, is the product of the first year. One new layer is formed each successive year, during the life of the plant.

695. ANNUAL CIRCLES. The ducts are usually first formed and lie in the inner part of the strata next the center, while the wood-fibers are produced toward the end of the season, and deposited in the outer part. The former are distinguished by the large size of their open ends, while the fibers are minute and compact. This circumstance renders the limits of each layer distinctly perceptible in a cross section, and their number, if counted at the base, will correctly indicate the age of the tree.

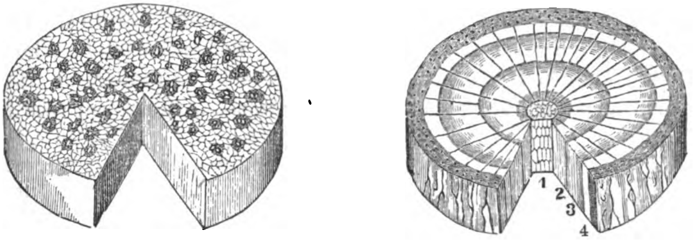
696. EXCEPTIONS. There are doubtless some exceptions to this rule. In tropical countries, where there is no distinction of seasons, there may be several zones deposited annually, or on the other hand, several or all the annual layers may be so blended by the uniform mixture of the ducts with the wood-tissue as to be undistinguishable. The layers of the beet-root are certainly not annual. They seem to correspond with the number of leaf cycles (§ 228).

697. THE ALBURNUM AND DURAMEN—the sap-wood and heart-wood, are well-known distinctions in the wood. The former, named from *albus*, white, is usually of a light color and softer structure. It is the living part of the wood through whose vessels mainly the sap ascends.

698. HOW FORMED. The interior layers of the alburnum gradually harden by the deposition of solid matter in their vessels, and the thickening of the cell-walls, until fluids can no longer pass through them.

Thus the *duramen* (*durus*, hard) is formed of a firm and durable texture, the only part valued as *timber*. Its varying colors in cherry, walnut, rose-wood, are well-known.

596 595



595, Cross-sections of an exogenous stem (Elm), of 2 years' growth ; 1, pith, 2, 3, annual layers of wood, next the cambium, 4, bark ; 596, and endogenous stem (Sorghum or Millet), where there is no distinction of layers.

699. **THE DURAMEN IS OF NO ACCOUNT IN VEGETATION**, and is in this respect dead. Hence it often decays, leaving the trunk hollow, and the tree at the same time as flourishing as ever.

700. **THE BARK** succeeds and replaces the epidermis, covering and protecting the wood. It is readily distinguished into three parts, viz.:

The inner, white bark (liber),
The middle, green bark (cellular),
The outer, brown bark (cortical).

The substance of all these is parenchyma and arranged, like the wood, in layers.

701. **THE LIBER** or white bark contains scattered bundles of pleurenchyma and cienchyma with its cellular tissue. Its wood-cells are very long (§ 666), called bast-cells, and are strengthened with secondary deposits until quite filled up. Hence the strength and toughness of flax and hemp. The strong material of "Russian matting" is from the liber of the linden-tree, and the "lace" of the South Seas from the lace-bark tree. The liber of other trees is not remarkable for strength.

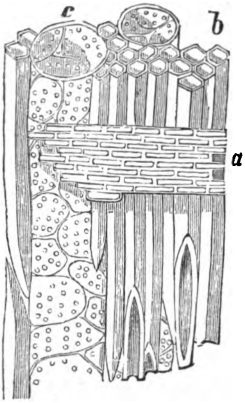
702. **THE CELLULAR OR GREEN BARK** succeeds to the liber. Its tissue resembles that of the leaf, being filled with sap and chlorophylle. It grows laterally to accommodate itself to the enlarging circumference of the tree, but does not increase in thickness after the first few years.

703. **THE CORTICAL** or brown bark. Its color is not always brown, being rarely white (canoe birch), or straw-color (yellow birch), or greenish (striped maple), or grayish (beech, magnolia). Its substance is always cellular tissue, but differing widely in consistency in different species. Its new layers come from within, formed from the green bark, while its older are sooner or later cast off.

704. **The cortical layers** sometimes accumulate to a considerable thickness (maple, hickory, oak), but are finally rent and furrowed by the expanding wood. In the cork oak (Quercus suber) they attain an excessive growth, furnishing that useful substance, *cork*. In birch (Betula papyracea) these layers resemble paper, long abiding by their elasticity the expansion of the trunk.

705. **The medullary rays** (*medulla*, pith) are those fine lines which appear in a cross-section passing like radii from the pith to the bark, intersecting the wood and dividing it into wedge-shaped bundles or sectors. They consist of firm plates of parenchyma (*muriform* tissue, the cell resembling brick-work) belonging to the same system with the pith.

597



597, Wood of Oak; section longitudinal, showing, *a*, medullary rays; *b*, wood-cells; *c*, porous ducts.

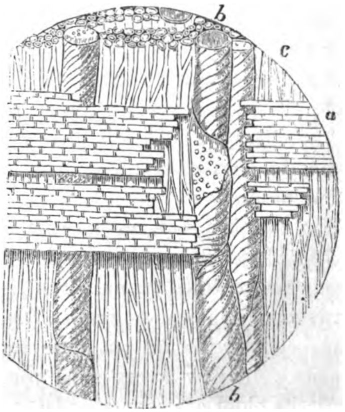
706. The medullary rays are no less frequent in the outer layer of wood than in the inner. Hence their number must increase yearly, and a new set commence with each successive layer, extending with those already formed through the subsequent layers to the bark, as shown in the diagram. (595.)

707. **The silver grain.** In a radial section (597, 598) the medullary rays are more conspicuous as shining plates of a satin-like texture, called the *silver-grain*, quite showy in oak, maple. A tangential section shows their ends in the form of thin ellipses.

708. **They serve as bonds** to combine into one firm body the successive wood layers, and as channels of communication to and from the bark and heart-wood. They also generate, at their outer extremities, the adventitious buds.

709. **The cambium layer.** Between the liber and the wood there is formed in the spring, at the time of the opening of the buds, a mucilaginous, half-organized layer of matter. Its presence loosens the bark and renders it easily peeled from the wood. The cambium is a sap solution of the starchy deposits of the preceding year, now rapidly being organized into cells.

598



598, Wood of Maple; *a* medullary rays; *b*, ducts; *c*, wood-cells.

710. **This is the generative layer** whence spring all the growths of the ligneous system. From this, during each growing season, two layers are developed, one of liber and one of wood, both at first a cellular mass, but the cells with wonderful precision transforming, some into the slender bast-cells of the liber, some into the dotted ducts and fusiform cells of the wood, some into the muriform tissue of the

medullary rays. Through these latter the quickening influence of the cambium pervades both wood and bark.

711. UNLIMITED GROWTH is therefore a characteristic of the exogenous stem: for the yearly increments are added to the outside of the wood, and the bark is capable of expansion by lateral growth to any extent.

712. THE PECULIAR SECRETIONS OF THE PLANT are generally more abundantly deposited in the bark than in the other parts. Hence the bark is more generally sought for its medicinal and chemical properties.

713. THE ENDOGENOUS STRUCTURE. In the cross-section of a monocotyledonous stem (corn, palm) there is no visible distinction of bark, wood, pith, or of annual layers of any kind.

714. IT IS COMPOSED of tissues quite similar to those of the exogenous stem, but very differently arranged. The body of the monocotyledonous stem consists of parenchyma, within which tissue numerous thread-like bundles of woody matter are imbedded.

715. THESE BUNDLES CONSIST EACH OF one or more dotted ducts accompanied by spiral vessels, pleurenchyma, and often cienchyma also, variously arranged in different species.

716. THE FORMATION OF THESE BUNDLES is dependent upon the leaves from which they may severally be traced downwards, first tending toward the interior of the stem. Further on they recurve outward again, and finally terminate near the surface, there interlacing and combining with their fellows and forming an excessively hard but inseparable rind (false bark).

717. CLEAVAGE DIFFICULT. From this entanglement of the fibers the cleavage of endogenous stems is difficult or impossible. In jointed stems (culms) this entanglement occurs only at the nodes (cane, grasses).

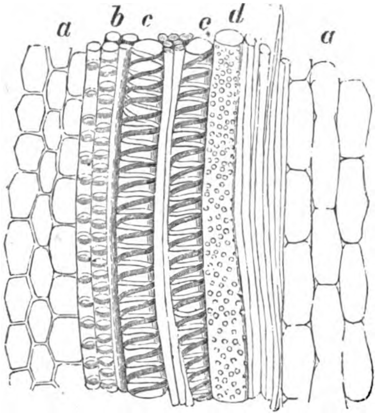
718. THE GROWTH of monocotyledonous stems thus takes place by the addition of the new wood bundles to the interior of the stem, and hence such plants are called *Inside-growers* or ENDOGENS.

719. PECULIAR FORMS of the caudex. The rind of endogenous trees is capable of only a limited expansion. This limit is soonest attained at the base of the stem long before the upper parts cease to enlarge. Consequently such trunks are often seen of equal or greater diameter at the summit than at the base: so the palmetto, corn, bamboo.

720. THE ACROGENOUS STRUCTURE is found in mosses, ferns, and the other higher tribes of the Cryptogamia. The stems advance, beneath or above the ground, full-formed, growing only at the end, hence called *Acrogens.*

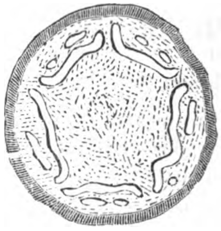
721. A CROSS-SECTION of a fern stem shows a body of parenchyma strengthened by an outer zone of fibro-vascular bundles, the whole invested with a sort of bark. The bundles are precisely similar to those found in the petioles, showing that the stem is the aggregate of the unaltered leaf-bases. (600.)

599



599. Various kinds of vessels in a wood-fiber of Bamboo or Rattan. *a*, Cells of parenchyma; *b*, annular cells; *c*, spiral vessels; *d*, porous duct; *e*, wood-cells.

600

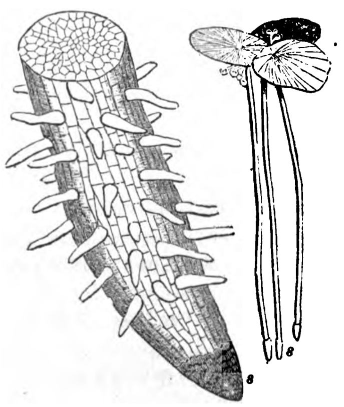


600, Section of an Acrogenous stem of Tree-Fern (Cyathea), showing the vascular bundles imbedded near the circumference of the cellular mass.

722. THALLOGENS are the lowest in the scale of rank, having no true axis and no other tissue than parenchyma, which grows in threads or in mass in all directions. The apparent stems (stipes), if any, support the fructification only (sea-weeds, lichens, mushrooms, puff-balls, frog-spittle, mildew).

723. THE STRUCTURE OF ROOTS presents few deviations from that of the stems to which they severally belong, being exogenous in Exogens, endogenous in Endogens, etc. In the former class the central pith disappears, its place being occupied mainly by vascular ducts, and the liber, if any, has no bast-cells.

601 602



601, Extremity of the rootlet of Maple, with fibrillæ and (*s*) *pileorhiza*. 602, Two plants of Lemna minor (Duckmeat). *s*, Their *pileorhiza*.

724. THE FIBRILLÆ and pileorhiza should, however, be mentioned as peculiar in the structure of the root. The former are produced by millions, clothing the delicate epidermis of the young rootlets as with cottony down, especially in light soils. They usually consist of a single cell of the epidermis extended as seen in figure 601. They are the true absorbents, the *mouths* of the growing plant.

725. THE PILEORHIZA. The microscope shows that the extreme, advancing point of the delicate, growing fibers is not thrust naked against the opposing soil, but is covered with a cap called *pileorhiza* (*pileus*, a cap, *rhiza*, root), which consists of older, hardened cells, behind which are formed the new cells. In the Duck-meat the pileorhiza is lengthened into a sheath.

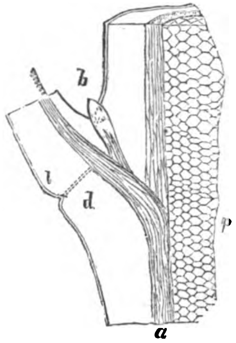
726. THE MANNER OF GROWTH IN THE ROOT is not like that of stems, by the extension of parts already formed, but simply by the addition of new matter at the

advancing point. This accounts for the wonderful facility with which it penetrates the soil and finds its way uninjured into the hardest earth.

727. Dictyogens. In those few Monocotyledons which bear reticulated leaves (Smilax, Dioscorea), the *Dictyogens* of Dr. Lindley, the roots exhibit a structure resembling that of exogenous stems.

STRUCTURE OF LEAVES.

603



603. Section of a stem at the origin of a leaf; *p*, cellular, or pith; *a*, vascular, the medullary sheath sending off a bundle into the leaf-stalk; *d*, the swelling (pulvinus) just below the articulation of the leaf-stalk (*l*); *b*, the axillary bud.

728. Nature of the leaf. The leaf may be regarded as an expansion of the two outer integuments of the bark, or of the green bark and the epidermis, expanded into a broad, thin surface by a woody framework proceeding from the medullary sheath and the liber.

729. The framework of veins is therefore fibro-vascular, abounding in spiral vessels, and strengthened with liber.

730. The parenchyma exists in two strata more or less distinct. In all those leaves which are ordinarily horizontal in position, one surface being upward and the other downward, these two layers are dissimilar; but in leaves with a vertical lamina (iris), and in phyllodia (§ 307) the two layers are similar.

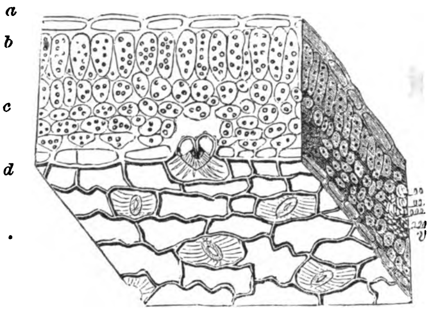
731. The layers described. The superficial layer of empty tabular cells, belongs to the epidermis. Next beneath this, in the surface on which the sun shines, are one or two layers of oblong cells placed perpendicularly to that surface, and more compact than the cells beneath them, which are pervaded by intercellular passages and by the veins.

732. Place of the stomata. The stomata as a rule belong to the *shaded* side of the leaf, avoiding the sun's direct rays. On the sunny side there are few comparatively or none. In the submerged leaves of water-plants the epidermal layer is hardly distinguishable, and is wholly destitute of stomata. In such leaves as float upon water (water lilies) stomata are found in the upper surface alone.

733. The chlorophylle. Within all the vesicles of the parenchyma are seen adhering to the walls the green globules of chlyrophylle, which give color to the leaf—dark green above, where it is more compact, paler beneath, where the cells are more loose and separate.

734. Vessels of cienchyma pervade the under-layer of parenchyma, returning the elaborated juices through the petiole into the cambium layer.

604



604, Minute portion of a leaf of Viola tricolor, viewed in perspective, showing, *a*, cells of epidermis above; *b*, compact parenchyma of the upper portion of the leaf; *c*, loose parenchyma; *d*, epidermal-cells of the lower surface with stomata, one cut and opening into the intercellular passages. (Magnified 100 diameters.)

735. THE STRUCTURE OF BRACTS, sepals, petals, and other organs, which are but modifications of the leaf, hardly requires a separate notice. The same kinds of vessels pervade their parenchyma, but the spiral exist in a larger proportion. In the pistil, the fibro-vascular bundles may be traced to the placenta, and thence into the funiculus and raphe of the ovule. In the more delicate organs chlorophylle is wanting, and the peculiar coloring, matter of whatever other tint, is uniformly diffused through the fluid contents of the cells of parenchyma. The depth of the tint depends on the number of cells thus colored.

CHAPTER V.

VEGETATION, OR THE PHYSIOLOGY OF PLANT LIFE.

736. NEXT INQUIRIES. We have now briefly surveyed the mechanism of the plant, both its outward forms and internal structure. We next inquire into the uses of all this wonderful apparatus; what the specific office which each part performs in the economy of the plant? and how do all parts coöperate in the work of living and growing?

737. THIS IS A SUBJECT OF GREAT EXTENT, and involves many inquiries of deep interest both in science and art,—many inquiries, also, which have never been answered. Our limits confine us to the bare statement of admitted principles, to the exclusion of all speculative discussion.

738. WHAT IS LIFE? This inquiry meets us at the beginning—a problem never solved. The spontaneous action of the plant, the self-determined shapes which it assumes, we at once refer to this principle, its vitality; but of the nature of this principle itself we can only say, Is it not a direct emanation from the Supreme Will, the Fountain of all life?

739. VEGETATION IS DOUBTLESS THE LOWEST FORM OF LIFE. It springs directly from inorganic or mineral matter, and is the first step in the organization of mineral matter. Its material is, therefore, mineral matter rendered *organic* through the vital force.

740. **The subordination of the vegetable** to the animal kingdom is thus manifest in its being fed and nourished on inorganic matter. It is interposed between these two incompatible extremes, and is ordained to transform the innutritious mineral into the proper and indispensable food of the animal kingdom.

741. **Parasitic plants** do indeed require the ready organized juices of other plants, just as the carnivora among animals live on flesh. Still the general fact remains, that plants alone feed on inorganic matter, and in turn become themselves the food of the animal kingdom.

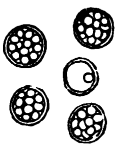
742. **The process of vegetatron** consists of imbibing the crude matters of the earth and air, transforming into sap, assimilating to plant juice (latex), and organizing into its own structure according to its own plan. The vital phenomena on which these transformations depend are called absortion, circulation, exhalation, assimilation, secretion, all of which processes take place in the individual cell. Therefore,

743. **Cell-life** is an epitome of the life of the whole plant. The cell is never a spontaneous production; it is the offspring of a pre-existing cell. So with the plant; it is always the offspring of a pre-existing embryo or cell. Nothing but a cell can produce or nourish a cell.

744. **Two kinds of organic matter** make up the cell. The first *protoplasm* or *protein* (C_{40} H_{31} O_{12} N_5), the material of the primordial utricle (§ 645), etc., *containing nitrogen;* 2d, *cellulose,* (C_{12} H_{10} O_{10}), the material of the outer wall or .crust, etc., *containing no nitrogen.* The former more nearly resembles animal matter, and is the seat of the vital force and chemical action.

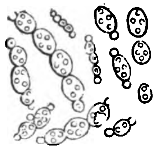
745. **What the cell imbibes.** Through the invisible pores of its walls the cell imbibes the fluid in which its food is dissolved, viz., sugar or dextrine, ammonia or some other nitrogenous substance. Such a fluid may be the flowing sap of the plant or any similar artificial mixture in which the cell is bathed, as (in the case of the yeast plant) a syrup with mucilage.

605



605, Protococcus viridis, the Green snow-plant.

606



606, Penicillum glaucum, the Yeast-plant.

746. **The chemical changes.** The sugar is thus brought into contact with the protoplasm in the cell, through whose action it is decomposed and its elements transformed into cellulose and water. Thus each atom of (grape) sugar or dextrine becomes

One atom of cellulose, C_{12} H_{10} O_{10}
and two atoms of water, H_2 O_2

C_{12} H_{12} O_{12}=grape sugar.

The water is exhaled with the rest; the cellulose is retained to incrust a new cell as soon as the primordial utricle shall next divide itself to form one. Or it may be deposited as starch granules for future use.

747. Action of chlorophylle. In the cells of green plants the globules of chlorophylle act an important part. Their formation depends upon the decomposition of carbonic acid (CO_2), the retention of the carbon, and the exhalation of the oxygen under the stimulus of the light. If the formation of cellulose continue beyond the present need for cell-formation, the excess is deposited in the form of starch-granules inclosed within the globules of chlorophylle, one in each.

748. Destination of the starch granules. When the starch granules are redissolved, they go to incrust the next new cell or to form a secondary layer in the old cell; or in autumn they go out into the general circulation and are at length stored up in the buds, the cambium, the roots, ready for an early use the following spring,

749. The increase of the protoplasm from the decomposition of the ammonia or other nitrogenous compounds present is a more intricate process, but no less evident, and when in excess, this also is deposited in minute globules of gluten, mucus, legumine, chiefly in seeds (wheat, beans, rice), in aid of germination.

750. The starch and gluten deposits of the wheat kernel are about sixty-eight and seventeen per cent. The former is found in the interior cells, the latter in the exterior, adjoining the pericarp or *bran*. In "flouring" some of the gluten adheres to the bran, and some constitutes the coarser meal, all of which is separated by the "bolt." *Extra flour* must, therefore, necessarily be deficient in gluten, the only element of the wheat which adapts it to the formation of *muscle*. A great error.

FERTILIZATION.

751. Capacity of the cell. Such being the vital energy of the cell, it is easy to admit the possibility of either its solitary existence as a plant (Protococcus, etc.), or of its associated existence, as in the living tissue of most plants.

752. Two modes of cell-growth. Now all plants, without exception, do actually commence existence in the state of a simple cell. But while in the lower plants (Cryptogamia), this simple cell, the plant-rudiment is at once discharged, free and independent, to float or grow, in the Phenogamia it is yet a while protected and nourished by other cells,—the cells of the ovule.

753. A distinction. This primitive cell-plant, after acquiring the requisite means, swells and divides itself into two or more new cells. If these new cells cohere into a tissue assuming a definite form, as in

the higher plants, the process is called *growth ;* but if they separate, each one still abiding separate, it is *reproduction.*

754. THE EMBRYONIC VESICLE is the expressive name of the embryonic cell of the Flowering Plants. It has its birth in that large cell of the nucleus of the ovule (§ 539) called the *embryo sac*, and is in some way developed from the cytoblast (§ 655). In appearance it may be like other new cells, but in the *impulse* or *instinct* with which it is endowed it is immeasurably different. It looks not to the mere continuation of an old series, but is the projector and pioneer of a new.

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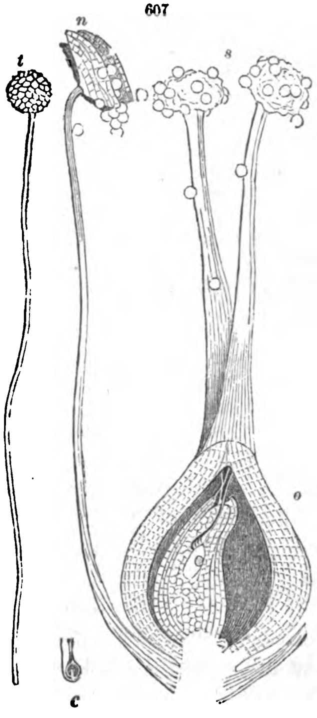

607, Section of the ovary of Polygonum Pennsylvanicum, in process of fertilization. (Magnified 20 diameters). *c*, Natural size. *n*, One of the stamens having discharged its pollen. *t*, A grain of pollen and its tube. *s*, Styles and stigmas. *o*, Ovary, ovule, embryo sac containing the embryonic globule. The extremity of a pollen tube is seen in contact with the embryo sac.

755. ITS NEW IMPULSE. Before it can enter upon its course of development so different from the destination of common cells, it must somehow be quickened and energized with an impulse in this new direction. In other words, it must be *fertilized*,—a process dependent on the pollen grains (§ 509).

756. THE POLLEN TUBE—ITS COURSE. When the pollen falls upon the stigma, it imbibes the saccharine moisture there, expands, and its inner, expansible coat of protoplasm protrudes through the aperture (one or more) of the outer crustaceous coat, in the form of an attenuated tube. This, like a radicle, sinks into the soft tissues of the stigma and style, reaches the ovary, and there meets and enters the micropyle of the ovule.

757. ITS CONTENTS, HOW DISCHARGED. At this juncture the ovule has so turned itself, whether orthotropous, anatropous, etc., as to present the micropyle favorable to this process. The pollen tube makes its way finally to the nucleus and penetrates to the embryo sac. Here its growth ceases; its point is applied externally to the sac, sometimes indents it; but (according to the most accurate observations), does not penetrate it. During this contact the contents of the tube pass by absorption into the sac.

758. GROWTH OF THE FERTILIZED CELLS. Immediately the embryonic globule, thus, somehow endowed with a new instinct, now

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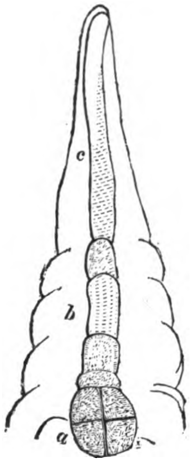

608, Growth of the embryo in Hippuris vulgaris. The fertilized cell has divided itself into several, of which *c*, *b*, constitute the *suspensor* attached to the apex of the sac; *a*, embryo dividing into 2, then into 4 cells.

first expands into a proper cell, and is usually attached to the wall of the sac near the micropyle. It then divides itself transversely, becoming two cells; the upper elongates either with or without subdivision, forming a filament (suspensor); the lower cell enlarges by subdivision, first spherically, and afterwards the little mass begins to take form according to the species, showing cotyledons, plumule, etc., until fully developed into the embryo.

759. **Schleiden's view.** Owing to the extreme difficulty of observation in this minute field, different views of this process have been advanced. That of Schleiden should not be overlooked. He maintains that the end of the pollen tube actually penetrates the sac and itself becomes the embryonic cell. The pollen grain is in this view the primitive cell, and is itself quickened into development by the contents of the embryo sac.

760. **Fertilization in the Coniferæ.** Where no style or stigma exists, as in the Coniferæ, the pollen falls directly into the micropyle of the naked ovule and its tubes settle into the tissue of the nucleus.

761. **Chemical changes** in germination. The ovule matures with the completion of the embryo, and passes into the fixed state of the seed in which the embryo sleeps. A store of nutritive matter, starch, gluten, etc., is thoughtfully provided in the seed for the use of the young plant in germination, until its root has gained fast hold of the soil.

762. **The changes which occur in the seed** at the recommencement of growth, are simply such as are requisite to reduce its dry, insoluble deposits to a solution which shall contain the proper materials for cell-formation or growth; that is, gluten and other nitrogenous matters, oil, starch, etc., are to be changed to *diastase*, the same as yeast, and *dextrine*, the same as gum or grape sugar.

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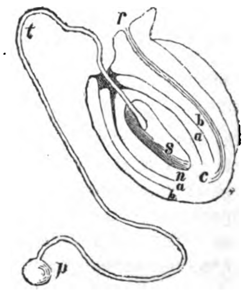

609, Ovule of Viola tricolor, showing the process of fertilization according to the views of Schleiden. *p*, Pollen; *t*, tube, *r*, raphe; *c*, chalaza; *b*, primine; *a*, secundine; *n*, nucleus; *s*, sac which the tube appears to have penetrated.

763. **The process.** To this end water and oxygen are absorbed, the gluten begins decomposition, forming yeast; fermentation ensues; heat is produced by the slow combustion of the carbon with oxygen forming and evolving carbonic acid, by which process some of the oil and starch is destroyed, while another portion gains water and turns to sugar. All this within the cells of the seed.

RIPENING OF FRUITS.

764. In the pericarps of most fleshy fruits (grape, pear, apple, peach, strawberry), sugar exists before germination, ready formed in the process of ripening.

765. **How the fruit grows.** In its earliest stages the pericarp consisted of a structure similar to that of green leaves, composed of parenchyma, pleurenchyma, vessels, and epidermis with stomata. Its distended growth afterwards results from the accumulation of the flowing sap, which here finds an axis incapable of extension. Thus arrested in its progress, it gorges the pistil and adjacent parts, is condensed by exhalation, assimilated by their green tissues, which still perform the office of leaves. Cell-formation goes on rapidly within, and the excess of cellulose is deposited in the cells as starch. Oxygen is usually absorbed in excess, acidifying the juices.

766. **How it ripens.** After the fruit has attained its full growth, the process of ripening commences, during which the pulp becomes gradually sweetened and softened chiefly by the change of the starch into more or less of soluble sugar.

767. **Honey.** In the same way we account for the production of honey in the flower. Copious deposits of starch are provided in the receptacle and disc (§ 446). At the opening of the flower, this is changed to sugar to aid in the rapid development of those delicate organs which have no chlorophylle wherewith to assimilate their own food. The excess of sugar flows over in the form of honey.

768. **The wise economy of the honey** is seen in fertilization. For, attracted by it, the insect enters the flower, rudely brushes the pollen from the now open anthers, and inevitably lodges some of its thousand grains upon the stigma!

769. **Experiment has proved** that in all these cases of the formation of sugar from starch oxygen is absorbed and carbonic acid evolved,—a process which we might expect, since starch ($C_{12} H_{10} O_{10}$) contains proportionably more carbon than sugar ($C_{12} H_{12} O_{12}$) contains. It is probable that these two phenomena in vegetation are always co-existent.

CHAPTER VI.

§ 1. ABSORPTION.

770. Office of the root. The absorption of liquids, containing in solution the food of the plant, is the peculiar and indispensable office of the root, as may be shown by an

771. Experiment. Take a small growing plant from the earth and immerse it by its roots, which should be nearly or quite entire, in a cup containing a definite quantity of water. Place near it another cup with a like quantity of water to indicate the amount of evaporation. The difference of the diminution in the two cups will be the amount of absorption. A plant of spearmint has thus been found to absorb more than twice its own weight per day. Every one is familiar with the rapid disappearance of water from the roots of potted plants, as Hydrangea, Oleander.

772. The absorbents. An impervious epidermis destitute of stomata everywhere clothes the roots, excepting its fibrillæ and the tender extremities of the rootlets. No part, therefore, is capable of absorption except the latter. But these, by their multiplied numbers, present an adequate absorbing surface to the soil.

773. Experiment. Let a growing radish be placed in such a position that only the fibrils at the end may be immersed in water;—it will continue to flourish. But if the root be so bent that the fibrils shall remain dry while the body of the root only is immersed, the plant will soon wither, but will again revive if the fibrils be again immersed.

774. Inference. Hence, in transplanting a tree almost the only danger to its life arises from the difficulty of preserving a sufficient number of these rootlets.

775. The force with which plants absorb fluids by their roots is surprisingly great, as shown by

776. Experiment. If the stem of a grape-vine be cut off when the sap is ascending, and a bladder be tied to the end of the standing part, it will in a few days become distended with sap even to bursting. Dr. Hales contrived to fix a mercurial gauge to a vine thus severed, and found the upward pressure of the sap equal to twenty-six inches of mercury, or thirteen pounds to the square inch.

777. But what causes this absorption of fluids in a direction contrary to gravitation? In explanation of this phenomenon reference has been made to two well-known principles in physics, viz., to *capillary attraction* by the tubular vessels and to endosmose by the closed cells, which are far more numerous.

778. Experiment. Invert the end of several open thermometer tubes in a colored liquid. It will be seen rising in the tubes above its level, to various heights—highest in the smallest calibre.

779. Exp. Suspend a napkin in such fashion that its lowest corner shall dip into a cup of water. In a few hours the water will have ascended into the napkin. These are results of capillary attraction.

780. Exp. Throw dried prunes, currants, or raisins into water. After a while they will have become swollen and distended with fluid. Now place them in strong syrup; they will again shrink.

781. Exp. Attach a bladder filled with syrup to a long glass tube, and immerse in water. The water flows in and the mixture arises slowly but forcibly in the tube. Reverse the liquids. Pure water from within the bladder will flow into syrup without. The former is a case of endosmose (*ἰνδον*, inwards, *μῶ*, to seek), the latter of exosmose (*ἐξω*, outwards).

782. Direction of the currents. The flow will continue until the two fluids are equal in density. In both cases there is also a flowing of syrup into the water, but the greater flow is always from the lighter into the denser fluid.

783. The force of endosmose is found to depend upon the excess in density of the inner fluid. Syrup, with the density of 1.3, caused a flow of water with an upward pressure of 4½ atmospheres (*Dutrochet*). The great force with which the capsule of the squirting cucumber (§ 606) bursts shows the power of endosmose. But a more probable theory is stated in § 791.

784. The use of absorption in the vegetable economy is not merely the introduction of so much water into the plant, but to obtain for its growth the elements of its food held in solution, whether gaseous or earthy. In attaining this object, the roots seem to be endowed with a certain power of selection or choice which we can not explain. Thus, if wheat be grown in the same soil with the pea, the former will select the *silica* along with the water which it absorbs in preference to the lime; the pea selects the *lime* in preference to the silica. Buckwheat will take chiefly *magnesia*, cabbage and beans, *potash*. This fact shows the importance of the *rotation of crops* in agriculture.

785. Other means of absorption. The office of absorption is not performed by the root alone. Every green part, but especially the leaf, is capable of absorbing gases and watery vapor.

786. Proofs. Every one knows how greatly plants, when parched and withered by drought, are revived by a shower which sprinkles their leaves without reaching their roots. Air plants or epiphites (§ 143), such as the long-moss and Epidendrum, must rely on this source chiefly for the supply of their food; and when the dissevered stems of such plants as the houseleek grow without roots, suspended by a thread in air, it is evident that all their nourishment comes through their leaves.

CIRCULATION.

787. Tendency of the flow. The fluids which are thus taken into the system by absorption can not remain inactive and stagnant. As their inward flow is regular and constant in its season, so must be their upward and outward flow, in a course more or less direct, toward the parts where they find an outlet or a permanent fixture.

788. In those Cryptogams which are composed of cellular tissue alone the circulation of the sap consists only of a uniform diffusion from cell to cell throughout the mass, as through a sponge.

789. In the higher plants, the different tissues perform appropriate

offices in the circulation, some conducting upward, some downward, some conveying the crude sap, some latex, and some air.

790. Air-vessels. Spiral vessels and others of the trachenchyma are generally filled with air, and take no part in the circulation of fluids, except in the spring, when the whole system is gorged with sap. The intercellular passages, also, generally circulate air alone.

791. The moving force. From the roots the newly absorbed fluid flows upward through the stems and branches, toward the buds, leaves, and flowers, being probably drawn thither into them by the exhalation and consequent exhaustion there going on.

792. Through what tissue. The tissue of the stem and branches through which the ascending sap loves chiefly to travel is the pleurenchyma—those long cells of the wood fiber, whether arranged in broad layers, as in the Exogens, or scattered in slender bundles, as in the Endogens.

793. Through which layers. And when the stem grows old, the sap ceases to traverse the inner layers,—the duramen, where its passage becomes obstructed by thickened cell walls, and frequents only the outer newer layers,—the alburnum, next adjoining the liber.

494. The crude sap. The fluid which thus flows upward seeking the leaves consists largely of water, is colorless, and is called the *crude sap.* It contains in solution minute quantities of gases and mineral salts, imbibed by the roots, together with dextrine and sugar (no starch) which it dissolved out of the cells on its way. This is the fluid which flows so abundantly from incisions made in trees in early spring.

795. The overflow of the sap depends upon the excess of absorption over exhalation. After the decay of the leaves in autumn, and the consequent cessation of exhalation, the rootlets, being deep in the ground, below the influence of frost, continue their action for a time, and an accumulation of sap in the system, even in the air-vessels and spaces, takes place. Also in early spring, before the leaves are developed, this action recommences, and the plant becomes gorged with sap, which will burst forth from incisions, as in the sugar maple, or sometimes spontaneously, as in the grape. As soon as the buds expand into leaves and flowers, the overflow ceases.

796. The true sap. Throughout its whole course to the leaves the sap gains in density by solution. There arrived, it loses by exhalation a large part of its water, gains additional carbon, and undergoes other important chemical changes (hereafter to be noticed), and becomes the *true sap*, dense and rich, both in nutritive matter for the *immediate* growth and in special products for the *future* nourishment of the plant.

797. Returning, the true sap distributes its treasures in due and exact proportion as needed to every organ. Its course lies in the tissues of the bark, cellular and woody, first distributed over the under surface

of the leaves, thence by the leaf-stalks into the liber, and so pervading all, down to the extremities of the roots.

798. ON ITS PASSAGE IT MAKES DEPOSITS of food, first in the cells, of the pith at the base of every incipient bud; then in the cambium region a copious store; next in the medullary rays a due portion, some carried outward for the supply of the cortical layer, and some inward for solidifying the wood; and lastly, the residue, often the richest legacy of all, falls to the root, and fills every branch and fiber, however vast its extent. This last deposit is that which is first met and dissolved by the rising tide of fluid in the following spring.

799. GROWTH PROGRESSES DOWNWARD. Since the flowing of the true elaborated sap is downward, it scarce admits of a doubt that the progress of the growth is also downward, from the leaves to the roots. And on no other supposition can we account for the results of the following

800. EXPERIMENT. Girdle an exogenous tree by removing an entire ring of its bark. It will flourish still during one growing season, and form a new layer of wood and bark everywhere above the wound, as before, but not at all below. The next season the tree will die. Why? Because the true sap returning can not descend to nourish the roots.

801. EXP. If a ligature be bound firmly around a stem (sc. of silver-leaf poplar) its growth is checked below, while the part just above will exhibit, after a year or two, a circular swelling evidently caused by the interruption of the descending sap.

802. EXP. If a chip be cut from the trunk, the wound heals evidently from the upper side.

803. EXP. Cut off the top of a branch just below a leaf. The upper remaining internode will perish. It has no leaf *above* it to send down its food.

804. EXP. Girdle carefully the stem of a potato-plant. No tubers will be formed below. And, again, girdle a fruit tree, and the fruit will for *once* be increased in amount.

805. IN A FEW INSTANCES TREES HAVE SURVIVED THE GIRDLING PROCESS. In such cases the medullary rays complete the broken currents. The descending sap, on arriving at the ring, flows inwardly by the medullary rays, making a circuit, and appears again in the bark below the interruption.

806. ROTATION. Beside this general circulation of fluids rising and falling from extremity to extremity, there is also a special circulation going on pretty constantly in each new cell, called *rotation*.

807. ROTATION is a flowing of the protoplasm in slender and devious currents on the inner surface of the primordial utricle, rendered perceptible by the opaque particles floating in it. The cytoblast also partakes of the movement. It is well observed in the hairs of Tradescantia, leaves of Vallesneria, and especially in the stems of Chara, where the current expands into an entire revolving layer of protoplasm. It is a vital movement.

TRANSPIRATION.

808. **Transpiration** relates to that important office performed by the leaves and other green organs, whereby pure water is separated from the crude sap and given off into the air. It takes place chiefly through the stomata, and is greatest by day and in a warm, dry atmosphere.

809. **Upon the activity of transpiration depends** also the amount of absorption. It not only makes room for the fluids from below to enter, but by disturbing their equilibrium, it creates an upward tendency, as the flame of a lamp draws the fluid up the wick. All the mineral and organic constituents of the sap are of course left in the plant.

810. **The quantity of pure water transpired** by plants is immense. A forest makes a damp atmosphere for miles around. Dr. Hales, in a series of instructive experiments in transpiration, ascertained that a sunflower three and a half feet high, with a surface of 5,616 square inches, transpired from 20 to 30 oz. in twelve hours; a cabbage, 15 to 25 oz. in the same time—equal to the transpiration of a dozen laboring men. We may easily

811. **Experiment** with a single leaf recently plucked, say of Podophyllum. Insert its petiole in a narrow-mouthed goblet of water, and around it fill the mouth with dry cotton to restrain evaporation. Over the whole place a bell-glass and expose to the sunshine. The vapor transpired will condense on the bell-glass, equaling (save the solid matters) the loss in the goblet.

RESPIRATION.

812. **Respiration** in plants refers to their relations to the atmosphere. So in animals. These relations are in either case vitally important.

813. **Experiment.** Place a small, healthy potted plant (sc. Geranium, Mimosa) under the receiver of an air-pump, and thoroughly exhaust the air. At once every vital process ceases—no absorption, no assimilation, no irritability, but speedily decay ensues. A vacuum would be no more fatal to a sparrow. Air is quite as necessary to the one as to the other.

814. **Illustration.** So also when only the roots are excluded from the air by being buried deeply in an embankment, the tree suffers injury and perhaps perishes.

815. **Respiration in plants, or aeration** (as sometimes called) consists of all those operations by which the sap is brought into contact with the air or subjected to its influence. It occurs in the intercellular passages, in the spiral vessels everywhere, but especially in the leaves and all other organs which have chlorophylle and stomata.

816. **The vital importance of respiration** is seen in the vast extent of the respiratory apparatus, consisting of millions of leaves and billions of breathing pores (stomata) and tracheæ (vessels)!

817. **The facts** connected with respiration, which seem to have been well established by the experiments of Saussure, Garreau, Moué, Draper, etc., are these:

1. Carbonic acid (CO_2) is absorbed by the leaves and all green tissues, under the direct solar light.

2. Oxygen (O) is absorbed by the leaves and all green tissues in the absence of direct solar light, and by the roots, flowers, fruits, and germinating seeds at all times.

3. The oxygen thus absorbed unites with some of the free (or nascent) carbon already in the tissues, and forms carbonic acid.

4. By a process of *assimilation* (§ 747) carbonic acid within the green tissues, from whatever source derived, is decomposed under the direct sunshine, and its carbon is retained; but

5. Its oxygen is set free and exhaled.

6. Carbonic acid is exhaled by the leaves and all the green tissues in the absence of the sunshine, and by all other parts (root, flowers, fruit, and germinating seeds) at all times. Hence it appears that there are

818. Two PHASES of aerial action constantly performed and seemingly opposed to each other. One dependent wholly upon the clear sunshine, in which, by the leaves, etc., CO_2 is absorbed, decomposed, and O returned to the atmosphere; the other, in which O is absorbed, and CO_2 exhaled, by the leaves in the absence of sunshine, and by all other parts (roots, flowers, etc.) at all times. Both are equally and vitally important.

819. THE FORMER PROCESS BECOMES VISIBLE to the eye by the rapid development of chlorophylle accompanying it, the latter by its gradual loss. Hence, during a protracted season of cloudy weather vegetation grows sensibly paler, but a few hours of sunshine restores the green to its wonted depth and richness.

820. BLANCHED PLANTS. Hence, also, plants growing in constant darkness and shade, as potatoes in the cellar, are very pale, and manifest their affinity for light by stretching themselves with famishing eagerness towards the slender sunbeam which gains admittance. Analysis shows structures thus grown to be deficient in carbon. We may easily repeat the

821. EXPERIMENT OF SAUSSURE. Place a quantity of freshly gathered leafy stems under a bell-glass full of rain-water, and thus expose them to the sun. Soon bubbles of gas arise and slowly collect above, pure oxygen gas, as long ago proved by Dr. Priestly.

822. REPEAT THE EXPERIMENT with boiled or distilled water, and no oxygen will appear. Rain-water contains CO_2 in solution, boiled water does not. The O must therefore have come from the CO_2 as would appear.

823. EXPERIMENT. Inclose air-tight in a glass globe the end of a leafy branch, without severing it from the tree. Thus it has been found by careful analysis after a day of sunshine that the proportion of O was increased at the expense of CO_2 within the globe; and *vice versa* by night or in the shade.

824. THE RESULTS of both transpiration and respiration, as concerns the plants, tend to concentrate the diluted sap by the elimination of the

water, which served merely for its conveyance, and to assimilate it into food capable of being organized into cells and their various contents.

And it is proper in this place also to notice *the effects* of this vast machinery upon the constitution of the atmosphere and its relation to the animal kingdom.

825. CARBONIC ACID gas is dissolved in the atmosphere and somewhat uniformly diffused throughout its whole extent in the proportion of about 4 parts in 10,000, or $\frac{1}{3250}$. This gas flows, and is ever flowing into the air from decaying animal and vegetable substances, from combustion, and from the breath of all living animals. The quantity thus added to the atmosphere annually is estimated at 100 billions lbs., or nearly one tenth of the whole amount of carbon, and yet it *does not accumulate.*

826. THE DEMAND AND SUPPLY. Were we able to compute in pounds the annual growth of the entire plant world, and the proportion of solid carbon which enters into that amount, we should doubtless find that the grand total of the demand equals this grand total supply.

A POISONOUS ATMOSPHERE. And further; not only are the necessities of the plant met by this wonderful circulation, but the necessities of animal existence also. Carbonic acid is poisonous, and should it be left to accumulate unchecked, it would gradually corrupt the air, and within a few centuries extinguish all animal life.

828. ANIMALS AND PLANTS MUTUALLY DEPENDENT. Thus are the two kingdoms of the organic world mutually, through the inorganic, dependent upon each other. The plant furnishes the oxygen which the animal consumes, the animal the carbonic acid which the plant consumes, while each would perish in an atmosphere of its own production. "Great and marvelous are thy works, O Lord of Hosts! in wisdom hast thou made them all."

CHAPTER VII.

REVIEW OF THE PRINCIPLES OF NUTRITION.

829. THE FOUR ORGANOGENS. It has already appeared in the preceding chapters that plants consist chiefly of four simple organic elements, viz.: carbon, oxygen, hydrogen, nitrogen. The first exists in a larger proportion, the last in a smaller than either of the others. Unitedly these four elements constitute about 94 per cent. of all vegetable matter.

830. **CARBON** (essentially charcoal) enters so largely into the composition of plants that it retains generally the exact form and texture of the wood after the other elements have been expelled by heat. On this element chiefly depends the solidity and strength. Its proportion is from 40 to 60 per cent. *Nitrogen*, although equally essential, is less abundant in the tissues, and exists largely only in certain vegetable products. as gluten, albumen, casein, theine.

831. **OXYGEN AND HYDROGEN** exist in plants combined with other elements, and also combined with each other forming water, especially in all fresh green vegetable matter. The water is expelled by drying, and the following table shows, in a few cases, the proportion for each 100 lbs.

Peas lose of water	8 lbs.	Apples and pears	83 lbs.
Wheat	14 lbs.	Red beet	85 lbs.
Rye and oats	15 lbs.	Strawberries and gooseberries.	90 lbs.
Wheat straw	26 lbs.	Turnips	93 lbs.
Potatoes about	75 lbs.	Watermelons	95 lbs.

832. **EARTHY ELEMENTS.** Besides these four universal elements, many other substances, earthy and mineral, are found in quantities greater or less, in different species. Thus forest-trees and most inland plants contain potassa; marine plants, soda, iodine; the grasses, silex, phosphate of lime; rhubarb and sorrel, oxalate of lime; leguminous plants, carbonate of lime; the Cruciferæ, sulphur, etc.

833. **THE PROPORTION OF EARTHY MATTER** is small and may be estimated from the ashes. As drying expels the water, so burning expels all other organic elements, and the inorganic earthy, whatever they be, remain in the form of ash. The following table from Bousingault is instructive on this point.

	Wheat		Oats		Yellow Peas.	Clover Seed.	Hay.	Turnips.	Potatoes.
	Grain.	Straw.	Grain.	Straw.					
Carbon	46.1	48.4	50.7	50.1	46.5	49.4	45.8	42.9	44.0
Hydrogen	5.8	5.3	6.4	5.4	6.1	5.8	5.0	5.6	5.8
Oxygen	43.4	38.95	36.7	39.0	40.1	35.0	38.7	42.2	44.7
Nitrogen	2.3	.35	2.2	.4	4.2	7.0	1.5	1.7	1.5
Ash	2.4	7.	4.	5.1	3.1	2.8	9.0	7.6	4.0
	100	100	100	100	100	100	100	100	100

834. **AGRICULTURAL CHEMISTRY.** Since all these elements are found in plants, we infer them to be essential ingredients in the food which they require for healthy vegetation; and an inquiry into the sources from which they may be supplied constitutes the chief object of Agricultural Chemistry.

835. **THE FOOD OF PLANTS** is air, earth, and water. It is evident that plants do not *create* a particle of matter, and therefore do not originate in themselves any of the elements which compose them. Consequently they must obtain them from sources without. Carbon is derived from the carbonic acid contained in the atmosphere, and from the decaying vegetable matter of the soil. Oxygen is derived from the

water and from the carbonic acid of the atmosphere; hydrogen from water and ammonia, and nitrogen from ammonia and nitric acid, drawn either from the atmosphere or the soil.

836. **THE ATMOSPHERE CONTAINS** about $\frac{1}{2500}$ part of carbonic acid, diffused throughout its whole extent; and as this gas contains 27 per cent. of carbon, it is demonstrable that the whole atmosphere contains more than 600 billions (600,000,000,000) of tons of solid carbon, derived from the sources already mentioned (§ 835),—an amount fully adequate to the demands of the vegetable kingdom.

837. **SOIL** consists of two classes of materials, viz.: mineral, and organic. The former, called *earths*, consists of disintegrated and pulverized rocks, including all the various mineral substances which are found to enter into the composition of plants, as potassa, soda, silica, lime, etc., all of which are more or less soluble in water. The *organic* materials consist of the remains of former tribes of plants and animals mingled with the earths; and which, having access to the air, are decomposed, evolving carbonic acid and ammonia both to the air and the water.

838. **WATER** is composed of oxygen and hydrogen ($H\,O$) in the proportion of 8 to 1 by weight, or one atom of each to each. Having pervaded the atmosphere in the state of vapor and rain, and percolated through the soil, it holds in solution carbonic and nitric acids, ammonia, and many of the various minerals above mentioned.

839. **AMMONIA** consists of nitrogen and hydrogen combined in the proportion of one atom of the former to three of the latter ($N\,H_3$). It arises from decaying animal and vegetable matter, as above stated, and is diffused through the atmosphere in the proportion of about 1 part in 10,000.

840. **NITRIC ACID** is also believed to yield nitrogen to plants. It consists of one atom of nitrogen to five of oxygen ($N\,O_3$). During thunder-storms it is generated in the air by lightning and brought down by rain. When combined with the *bases*, as potassa, soda, etc., it forms *nitrates*—substances known to be efficient fertilizers in soils.

841. **AIR PLANTS.** Thus it appears that water, carbonic acid and ammonia (or nitric acid) may yield to plants their four essential organic elements. And since all of them are contained in the atmosphere, some plants are capable of subsisting on air alone (long moss, lichens); but most species are dependent on water, earth, and air, and demand a copious supply.

842. **THE EXTERNAL CIRCUMSTANCES**, therefore, first requisite to healthy vegetation are,—1, free access to an atmosphere which is often agitated by winds; 2, a proper supply of rain or river water; 3, a soil possessing the peculiar minerals required by the species to be grown upon it, together with a certain proportion of vegetable mold.

843. **THE SUPPLY.** The first of these is everywhere abundantly supplied by nature, and asks no aid from man. The second and third are often deficient, and are to be supplied by the labors of agriculture. By *irrigation* streams of water are turned from their natural channels to add to the scanty moisture of fields parched with drought; by *drainage* the inundated bog is converted into a luxuriant lawn.

844. **THE OBJECT OF TILLAGE** is to pulverize and lighten the too compact soil; and thus expose every part to the oxygen of the air in order to hasten its decomposition. *Subsoiling*, or deep ploughing, is an operation whereby that stratum of earth

which lies just below the ordinary soil is moved and subjected to atmospheric influence. The subsoil, with less organic matter, contains often soluble fertilizing earths which may thus be rendered available for the use of plants.

845. **The object of manuring** is mainly to increase the quantity of organic matter, or to restore to the soil those qualities which have been taken away by the crops. By various *amendments* (as gypsum, lime, charcoal) ammonia is strongly attracted from the air and yielded again to vegetation. Marl promotes the decomposition of the soil, and ashes add to the potassa—a substance which also exists naturally in soils, being derived from the decomposition of the rocks which contain it, as granite, clay-slate, basalt, etc.

846. **Bone manure** is rich in the phosphates indispensable in the formation of albumine, gluten, and other blood-making qualities of fruits. The mineral phosphate of lime, bone-chalk, etc., are of the same nature.

847. **Guano** is a manure whose great value depends upon its abundant nitrates and ammoniacal salts. It is the excrement of sea-fowl which has for ages accumulated in vast deposits on certain coasts and islands of South America and Africa.

848. **Fallow ground.** Soils are often improved by lying fallow for a season, thus allowing time to form, by decomposition, a fresh supply of that particular ingredient which had been exhausted by previous crops. On the same principle is explained the beneficial effects of a rotation of such crops as require different mineral substances in their composition.

849. **Light and heat.** After all these materials have been supplied to the plant, still two other agents are requisite, without which the great work of vegetation will not go on. These life-giving principles are light and heat, both of which emanate in floods from the sun. Under their influence the *raw material* is received into the vessels of the plant and assimilated to its own substance—a process which can be fully comprehended only by Him whose power is adequate to carry it on.

850. **Digestion.** Under the influence of solar light and a temperature above the freezing point, water holding various earths in solution is imbibed by the roots and raised into the tissues of the stem, dissolving as it passes small portions of gum or sugar previously deposited there. In this state it is *crude sap*. Passing on it enters the leaves, and is there subjected to the action of the chlorophylle (§ 657) which chiefly constitutes the apparatus of digestion. Here it is concentrated by transpiration, sending off quantities of pure water. Meanwhile the leaves are imbibing carbonic acid from the air, decomposing it, retaining the carbon, and returning pure oxygen. Thus elaborated, the sap is now called

851. **The proper juice**, consisting evidently of carbon and water, with a little nitrogen and minute portions of the mineral substances mentioned above. From this, the vital fluid, are elaborated the building material of the vegetable fabric, and all its various products and secretions.

852. **Protein, or protoplasm**, the substance of the primordial utricle, analogous in composition to the living tissues of animals, and containing nitrogen, is organized, first of all, from this vital fluid. *Cellulose* (or lignin) next, the peculiar principle of vegetable tissue, whether cellulal, vascular, or woody, consisting of carbon with the

exact elements of water, viz., $C_{12}\ H_{10}\ O_{10}$. Then, through the action of light, *chlorophylle* springs into being, clothing the plant in living green. Meanwhile

853. GUM, STARCH AND SUGAR, nutritive products common to all plants, are also developed from the proper juice—not all to be immediately employed in building up the tissues, but mostly to be stowed away in reserve for future use. Such deposits are made in the root of the beet, tuber of the potato, and in the fruit generally. These three products, with cellulose, are all composed of carbon and the elements of water, often in identical proportions ; thus cane sugar is $C_{12}\ H_{12}\ O_{12}$; grape sugar, $C_{12}\ H_{11}\ O_{11}$; gum, $C_{12}\ H_{10}\ O_{10}$; starch, $C_{12}\ H_{10}\ O_{10}$; cellulose, $C_{12}\ H_{10}\ O_{10}$.

854. SUGAR IS SOMETIMES PRODUCED DIRECTLY from the proper juice, as in the root of beet, stalk of maize, and sugar-cane ; but oftener, during germination, from the starch deposited in the seed. Its composition, as seen above, differs from that of starch only in containing a larger proportion of the elements of water or (what is the same) a smaller proportion of carbon. As starch is insoluble, its transformation into soluble gum or sugar is needful to render it available for the nutrition of the growing embryo.

855. THE FACILITY WITH WHICH THESE FIVE GENERAL PRODUCTS ARE CONVERTED INTO EACH OTHER, both in the growing plant and in the laboratory of the chemist, is accounted for by the similarity of their chemical condition. Thus starch, gum and cellulose may reconvert merely by some change in the arrangement of their constituent atoms, or they may become sugar by the addition of one or two atoms of water.

856. AMONG THE NUMEROUS SECRETIONS of plants, which our limits forbid us to consider, are the vegetable acids containing more oxygen proportionately than exists in water ; the oily acids, resins and oils, containing less oxygen than exists in water, or none at all. These substances vary in the different species almost to infinity, taking into their constitution, in addition to the *four organogens*, minute portions of the mineral substances introduced by rain and river water. Their peculiarities of odor, flavor, color, properties, etc., although so obvious to the senses, are occasioned by differences of constitution often so slight as to elude the most delicate tests of the chemist.

857. THE FOLLOWING TABLE CONTAINS examples of the various classes of secretions, arranged in reference to their relative proportion of oxygen :—

CLASS.	NAME AND SOURCE.	FORMULA.	
Acids highly oxygenized.	Oxalic, Leaves of rhubarb, sorrel, etc.,....	$C_2\ H\ O_4$	The proportion of oxygen to hydrogen is greater than in water.
	Citric, Fruit of the Orangeworts,.........	$C_{12}\ H_8\ O_{14}$	
	Mallic, Apples and many fruits,..........	$C_8\ H_6\ O_{10}$	
	Tartaric, Juice of grapes,...............	$C_8\ H_6\ O_{12}$	
	Gallic, Nutgalls.......................	$C_{14}\ H_6\ O_{10}$	
	Tannic, Astringent barks, nutgalls,.......	$C_{18}\ H_6\ O_8$?	
	Meconic, Juice of the Poppyworts,.......	$C_{14}\ H_4\ O_{14}$	
Neutral substances. Mild, nutritious.	Grape sugar. Grapes, raisins, honey,....	$C_{12}\ H_{12}\ O_{12}$	The oxygen proportioned to hydrogen equally, as in water.
	Cane sugar. Maple, maize, sorghum,.....	$C_{12}\ H_{11}\ O_{11}$	
	Starch. In all plants,..................	$C_{12}\ H_{10}\ O_{10}$	
	Gum, mucilage. Common,.............	$C_{12}\ H_{10}\ O_{10}$	
	Cellulose. Substance of cellular membrane,	$C_{12}\ H_{10}\ O_{10}$	

CLASS.	NAME AND SOURCE.	FORMULA.	
Neutral principles, bitter, acrid, coloring.	Phloridein. Bark of cherry, apple, etc.,	$C_{12} H_7 O_6$	Oxygen in proportion slightly less than water.
	Salicine. Bark of willow,	$C_{13} H_9 O_7$	
	Populine. Bark of aspen (Populus),	$C_{20} H_{11} O_8$	
	Meconine. Juice of poppy,	$C_{10} H_5 O_4$	
	Alizarine (Turkey red). Madder,	$C_{37} H_{12} O_{10}$	
Essential, volatile oils, oxygenated.	Oil of anise. Pimpinella anisum,	$C_{16} H_8 O_4$	Oxygen in diminished proportion.
	Oil of cinnamon. Laurus cinnamomum,	$C_{18} H_8 O_2$	
	Oil of clover. Caryophyllus aromaticus,	$C_{24} H_{15} O_5$	
	Oil of sassafras. Laurus sassafras,	$C_{10} H_5 O_2$	
	Oil of peppermint. Mentha piperita,	$C_{24} H_{20} O_2$	
	Oil of valerian. Valeriana officinalis,	$C_{12} H_{10} O_2$	
Volatile acids derived from oils.	Valeric acid. Root of valerian,	$C_{10} H_{10} O_4$	In this series the proportion of oxygen regularly diminishes.
	Enanthylic. Castor-oil nut,	$C_{14} H_{14} O_4$	
	Pelargonic. Rose geranium,	$C_{18} H_{18} O_4$	
	Lauric. Laurus nobilis,	$C_{24} H_{24} O_4$	
	Myristic. Nutmegs,	$C_{28} H_{28} O_4$	
	Behmic,	$C_{44} H_{44} O_4$	
	Melissic,	$C_{60} H_{60} O_4$	
Resins, gum-resins, balsams, and camphors.	Colophony, or resin of pine, etc.,	$C_{20} H_{14} O_2$	very little oxygen remaining.
	Resin of Copaiva. Copaifera,	$C_{40} H_{31} O_4$	
	Resin of Mastic. Pistacia lentiscus,	$C_{40} H_{31} O_2$	
	Resin of Copal. Hymmæa, etc.,	$C_{40} H_{31} O_8$	
	Camphor. Laurus camphora,	$C_{20} H_{16} O_2$	
	Borneo camphor. Dryobalanops,	$C_{20} H_{18} O_2$	
Volatile oils, non-oxygenized.	Oil of turpentine. Pines,	$C_5 H_4$	Carbo-hydrogens, isomeric, destitute of oxygen.
	Bergamot. A variety of orange,	$C_5 H_4$	
	Black pepper. Piper nigrum,	$C_5 H_4$	
	Juniper, savine. Juniperus,	$C_5 H_4$	
	Parsley, cubebs, etc.,	$C_5 H_4$	
Oxygenated alkaloids.	Quinine. Peruvian bark,	$C_{28} H_{22} O_4 N_2$	Oxygen less than hydrogen.
	Morphine. Opium, poppy,	$C_{34} H_{19} O_6 N$	
	Theine. Leaves of the tea-plant,	$C_{66} H_{10} O_4 N_4$	
Alkaloids.	Nicotine. Tobacco (Nicotiana),	$C_{20} H_{14} N_2$	Oxygen none.
	Coneine. Hemlock (Conium),	$C_{16} H_{15} N$	
Volatile.	Oil of mustard. Sinapis nigra,	$C_{16} H_5 N S_2$	Oxygen none.
	Oil of horse-radish. Cochlearia,	$C_{16} H_5 N S_2$	
	Oil of garlic. Allium sativum,	$C_6 H_5 S$	
Organic compounds.	Protein. Primordial utricle,	$C_{36} H_{25} O_{10} N_4 = Pr.$	
	Gluten. The cereal grains,	$10 Pr + S$	
	Casein. Leguminous seeds,	$10 Pr + P + S$	
	Albumen. Many seeds,	$10 Pr + P + 2 S$	

PART THIRD.

SYSTEMATIC BOTANY.

CHAPTER I.

OF THE CLASSIFICATION OF PLANTS.

858. **Systematic botany** relates to the arrangement of plants into groups and families, according to their characters, for the purpose of facilitating the study of their names, affinities, habits, history, properties and uses.

859. **In this department**, the principles of Structural and Physiological Botany are applied and brought into practical use in the discrimination of the different groups, and the limitation of their characters. Besides the immediate uses of Systematic Botany in the determination of species and kinds, as above stated, it accomplishes

860. **Another purpose of still higher import.** It aids us in studying plants as related to each other, and constituting one great and glorious system. It shows us the Almighty Creator at once employed in the minutest details and upon the boundless whole, equally attentive to the perfection of the individual in itself, and to the completeness of the grand system, of which it forms a necessary part.

861. **The subject of great extent.** The study of classification introduces the botanist into an extensive field of inquiry. The subjects of his research meet him at every step. They clothe the hill and plain, the mountain and valley. They spring up in the hedges and by the way side. They border the streams and lakes and sprinkle over their surfaces; they stand assembled in vast forests, and cover with verdure even the depths of the ocean. Now, with each individual of this vast kingdom the botanist proposes to acquaint himself, so that he shall be able readily to recognize its name, and all that is either instructive, interesting, or useful concerning it, whenever and wherever it is presented to his view.

862. **The wrong way to study.** Now it is obvious that if the student should attempt the accomplishment of this labor by studying each and every individual plant in detail, whether with or without the aid of books, the longest life would scarcely suffice him for making a good beginning. But such an attempt would be as unnecessary as fruitless. The Author of Nature has grouped these myriads of individuals into

863. **Species** (§ 76). When He called plants into existence, in their specific forms, He endowed each with the power of *perpetuating its own kind and no other*, so that they have descended to us distinguished by the same characters and properties as at the beginning. When, therefore, the student has formed acquaintance with any individual plant, he is also acquainted with *all other individuals belonging to the same species.*

864. **For example**: a single plant of *white clover* is a true representative of all the millions of its kind that grow on our hills and in our meadows; and a single description of the *white pine* will answer in all essential points for every individual tree of that noble species, in all lands where it is found.

865. **Genera.** Although the species are separated from each other by clear and definite distinctions, still they are found to exhibit also constant affinities, whereby they stand associated into larger groups called genera (§ 80). *A genus*, therefore, is an assemblage of related species, having more marked affinities with each other in general structure and appearance than they have with other species.

866. **For example**: the white clover and the red (Trifolium repens and T. pratense) are universally recognized as different species, but of the same genus; and a single *generic* description of one plant of the genus Trifolium will convey intelligence to a certain extent concerning every other plant belonging to its 150 species.

867. **Thus** are the individual plants of the globe grouped by descent and resemblance, and comprehended under species; and the species associated into higher groups called genera. "An individual," says Prof. Forbes, "is a positive reality; a species is a relative reality; a genus is an idea—but an idea impressed on nature, and not arbitrarily dependent on man's conceptions. An individual is one: a species consists of many resulting from one; a genus consists of more or fewer of these *manies resulting from one* linked together, not by a relationship of descent, but by an affinity dependent on a Divine idea."

868. **Orders.** But natural affinities do not end here. The genera are yet too numerous for the ready and systematic study of the naturalist. He, therefore, would generalize still further, and reduce the genera to still fewer and broader groups. On comparing the genera with each other, he finds that they also possess in common certain important characters which are of a more general nature than those which distinguish them from each other. By these general characters the genera are associated into orders.

869. **For example**: comparing such genera as the mustard, radish, cabbage, cress, wall-flower, etc., it is seen that, while they differ sufficiently in their generic characters, yet they all have certain marked resemblances, in their didynamous stamens, siliquous fruit, whereby they are obviously associated into the same order —the Cruciferæ. So, also, the pines, the spruces, the cedars, the larches, and the cypress, while as genera they are obviously distinct, yet all bear *cones* of some form, with naked seeds; hence they are naturally grouped into one Order—the Coniferæ.

870. **Classes.** In like manner the Orders, by characteristics of resemblance still more general, are associated into a few groups, each of great extent, called Classes, whether natural or artificial.

871. **Intermediate groups**, formed on the same principles, are recognized as Subgenera, Suborders or Tribes, and Subclasses or Cohorts, which will be further noticed and described in another place.

872. **Methods of classification.** Two independent and widely different methods of classifying the genera have been generally approved, the Artificial System of Linnæus, and the Natural System of Jussieu. The former is founded solely on characters relating to the organs of fructification, leaving all other natural affinities out of view. The latter, on the contrary, takes for its basis all those natural affinities and resemblances of plants whereby Nature herself has distinguished them into groups and families.

CHAPTER II.

THE ARTIFICIAL SYSTEM.

873. **A system of classification is said to be artificial when**, disregarding the real nature of the subjects classified, it rests merely on some obvious external circumstance. As when the books of a library are arranged on shelves according to their *size*, octavo, duodecimo, etc., or as when the words in a language are arranged in dictionaries, *alphabetically*, forming thus class A, class B, etc. In either case the books or the words constituting any group may be quite diverse in character, having nothing in common except their octavo size or initial letter. The only use of such an arrangement is convenience of reference.

874. **Carl von Linné** (Linnæus) of Sweden, born in 1707, everywhere honored as the father of systematic and descriptive botany, was the author of that renowned artificial system which bears his name. For well nigh a century it continued in almost universal use, and was regarded by his followers with far more respect than by Linnæus himself, who designed it simply as an index or clue to the vegetable kingdom. For he says (Philosophia Botanica) "Methodi Naturalis fragmenta studiosè inquirenda sunt. Primum et ultimum hoc in Botanicis desideratum est."

875. **Considered as a system**, the Linnæan arrangement totally fails to exhibit those true relations and affinities of plants which render the knowledge of each kind a guide to that of the others, and combine all into one consistent whole. It can not, therefore, properly be regarded as a *system*.

876. **Considered as an index** or key to the vegetable kingdom, it is by no means reliable, for the stamens and styles often vary numerically in the same plant; and secondly, the species of the same genus often vary in these respects, thus obliging us to violate even specific affinities; and again, when the stamens or pistils are accidentally marred, or lost, or immature, the index must also fail of its purpose. For these reasons this arrangement has fallen into disuse, having been superseded by the Natural System, and by other arrangements better adapted to the present advanced state of the science. Yet being intimately connected with the history of botany, and having largely contributed to its early progress, its outlines at least demand a record in our pages.

877. **The Linnæan System** proposes to arrange all the known genera of plants under *twenty-four classes*, each based on some special character derived from the essential floral organs, as follows:

§ 1. THE FIRST THIRTEEN CLASSES comprehend all such plants as have their flowers all perfect, their stamens unconnected and and of equal length, or at least neither didynamous nor tetradynamous.

Class I. MONANDRIA,—one stamen to each flower (Saltwort, etc.).
Class II. DIANDRIA,—two stamens (Circæa, Veronica).
Class III. TRIANDRIA,—three stamens (Iris. Nearly all the Grasses).
Class IV. TETRANDRIA,—four stamens (Galium, Plantago).
Class V. PENTANDRIA,—five stamens (Vitis, Conium).
Class VI. HEXANDRIA,—six stamens (Lily, Tulip, Luzula).
Class VII. HEPTANDRIA,—seven stamens (Trientalis).
Class VIII. OCTANDRIA,—eight stamens (Erica, Œnothera).
Class IX. ENNEANDRIA,—nine stamens (Rheum, Sassafras).
Class X. DECANDRIA,—ten stamens (Dianthus, Rhododendron).
Class XI. DODECANDRIA,—twelve to nineteen stamens (Asarum).
Class XII. ICOSANDRIA,—twenty or more stamens, perigynous (Rosa).
Class XIII. POLYANDRIA,—twenty or more stamens, hypogynous (Ranunculus, Papaver).

§ 2. THE NEXT TWO CLASSES are founded on the relative length of the stamens, the flowers being perfect and stamens generally unconnected.

Class XIV. DIDYNAMIA,—four stamens, two long and two short, by pairs, as in Antirrhinum, Prunella.
Class XV. TETRADYNAMIA,—six stamens, four long and two short, as in the wall-flower and the Cruciferæ generally.

§ 3. THE NEXT FOUR CLASSES are determined by the connection or union of the stamens.

Class XVI. MONADELPHIA,—stamens united by their filaments into one set, as in Malva, Geranium.
Class XVII. DIADELPHIA,—stamens united by their filaments into two sets (Polygala, pea, Lathyrus).
Class XVIII. POLYADELPHIA,—stamens united by their filaments into three or more sets (Hypericum).
Class XIX. SYNGENESIA, stamens united by their anthers, as in the Asters and other Compositæ.

§ 4. THE NEXT CLASS DEPENDS for its character upon the adhesion of the stamens with the pistil.

Class XX. GYNANDRIA,—stamens and styles united, forming a column, as in Orchis, Asclepias.

§ 5. THE NEXT THREE CLASSES include all plants with diclinous flowers, some with pistils, some with stamens only.

Class XXI. MONŒCIA,—staminate and pistillate flowers, both upon the same plant (Pinus, Arum, Hazel).
Class XXII. DIOECIA,—staminate and pistillate flowers on separate plants (Willow, Hemp, Hop, Smilax).
Class XXIII. POLYGAMIA,—staminate, pistillate and perfect flowers either on the same or on different plants, as in Acer, Acacia, Veratrum).

§ 6. THE LAST CLASS includes flowerless plants.

Class XXIV. CRYPTOGAMIA,—plants in which the organs of fructification are concealed (as the name implies) as in ferns, mosses, seaweeds.

878. THE LINNÆAN ORDERS. Each class is subdivided into orders, and these also are founded on some condition of the essential organs. The orders of the first thirteen classes are determined by the number of styles (or stigmas when the styles are wanting) in each flower.

Order 1.	Monogynia,	1 style.
Order 2.	Digynia,	2 styles.
Order 3.	Trigyina,	3 styles.
Order 4.	Tetragynia,	4 styles.
Order 5.	Pentagynia,	5 styles.
Order 6.	Hexagynia,	6 styles.
Order 7.	Heptagynia,	7 styles.
Order 8.	Octogynia,	8 styles.
Order 9.	Enneagynia,	9 styles.
Order 10.	Decagynia,	10 styles.
Order 11.	Dodecagynia,	12 styles.
Order 12.	Polyginia,	more than 12.

879. THE ORDERS OF CLASS XIV. depend upon their seed vessels.

Order 1. Gymnospermia—Fruit four achenia, as in the Labiatæ.
Order 2. Angiospermia—Fruit inclosing several seeds.

880. THE ORDERS OF CLASS XV. also depend on the fruit.

Order 1. Siliculosa—Fruit a sillicle, as in pepper-grass.
Order 2. Siliquosa—Fruit a silique, as in wall-flower.

881. THE ORDERS OF CLASSES XVI., XVII., XVIII. are distinguished by the number of stamens and named like the first classes.

Order 1. Triandria—three stamens united by their filaments.
Order 2. Pentandria—five stamens united by their filaments.

882. THE ORDERS OF CLASS XIX. are five, as follows:

Order 1. Equalis—Florets of the head all perfect (☿).
Order 2. Superflua—Florets of the disk ☿, of the ray ♀.
Order 3. Frustranea—Florets of the disk ☿, ray abortive.
Order 4. Necessaria—Florets of the disk ♂, of the ray ♀.
Order 5. Segregata—Each floret with a separate involucre.

883. THE ORDERS OF CLASSES XX., XXI., XXII. distinguished in the same way as the first thirteen, the XVI., XVII., XVIII. classes; as

Order 1. Monandria—one stamen. Order 2. Diandria—two stamens. Order 3. Triandria—three stamens, etc.

884. THE ORDERS OF CLASS XXIII. are founded on the position of the flowers relatively, thus:

Order 1. Monœcia—Flowers ☿; ♂, ♀ on the same plant (Acacia).
Order 2. Diœcia—Flowers ☿ on one plant, ♂, ♀, on another (Chamerops).
Order 3. Triœcia—Flowers ☿, ♂, and ♀, each on separate plants.

885. THE ORDERS OF CLASS XXIV. are the same as in the Natural System, and can not be defined by a single character.

Order 1. Felices, ferns.
Order 2. Musci, mosses.
Order 3. Hepaticæ, liverworts.
Order 4. Lichens, lichens.
Order 5. Fungi, mushrooms.
Order 6. Algæ, seaweeds.

CHAPTER III.

THE NATURAL SYSTEM.

886. **The aim of the Natural System** is to associate plants into groups and families according to their true natural likenesses and affinities, and thus to make an expression, so far as possible, of the Divine plan in the System of Nature.

887. **It differs from the artificial** arrangement: while that employs only a single character in classification, the natural system regards the total organization, and seizes upon every character wherein plants agree or disagree, and forms her associations only upon the principle of natural affinity. Hence each member of any natural group resembles the others, and a fair description of one will serve, to a greater or less extent, for all the rest.

888. **The species and genera** are formed on this principle of classification, as above stated, and are truly natural associations. Individuals altogether similar, cast as it were in the same mold, constitute a species. Species agreeing in nearly all respects and differing but in few constitute a genus. Thence the genera, associated by their remaining affinities into groups of few or many, by this same method are organized into Natural Orders and other departments of the vegetable kingdom.

889. **Relative value of characters.** Although the natural method employs every character, yet it does not regard all of equal value or importance. As a rule, the higher the physiological importance of any organ, the higher will be the value of the characters which it affords.

890. **Because,** (1) the less will it be subject to variation, and (2) the more general in respect to other organs will be the resemblance of those plants which agree in respect to that organ. Thus, *first* in value are those characters drawn from the cellular tissue; *second*, from the vessels, the stomata, the embryo, and albumen; *third*, from the axis and leaves, the stamens, pistils, and fruit; *fourth*, from the perianth; *fifth*, from the inflorescence and bracts.

891. **History of the natural method.** Its foundation was first laid 1682, by John Ray, of England. He separated the Flowering from the Flowerless plants, and divided the former into Dicotyledons and Monocotyledons. Linnæus, about 50 years later, constructed a fragment of the system, consisting of the names of 67 natural orders, without descriptions. But to Antoine de Jussieu is due the honor of the final establishment of this Method upon the true principles of natural affinity. He arranged the genera then known (A. D. 1780) into 100 natural orders, defining them with so much exactness, that nearly all have withstood the test of time; and have been adopted into our present systems. Robert Brown contributed largely to its completion and introduction into England, by the publication of his Flora of

New Holland in 1810; and finally De Candolle, by the publication of his great work "Prodromus Systematis Naturalis Regni Vegetabilis", commenced in 1816, and designed as the universal Flora, brought this system into general use.

892. **Many systems.** But the aim of the natural system as an expression of the Divine Order of Nature is not yet consummated. The lower divisions of the System —species, genera, and orders,—are well defined and settled as truly natural groups. The grand divisions also,—Cryptogamia, Phenogamous Exogens and Endogens (§ 897),—are fully established. But in the midst, between these extremes, there is a region of uncertainty, respecting the arrangement of the orders into groups subordinate to the grand divisions, viz., into Classes and Subclasses. In this matter, authors have maintained different views, and proposed a variety of systems.

893. **The difficulty** lies in this. We attempt necessarily a *linear* arrangement of the orders, placing one after another in succession, thus regarding the affinities of each in two directions only, viz., toward the preceding and the succeeding; whereas each order should be regarded as a center of affinities; being related immediately to all others lying *around* it, as a province on a geographical map is related equally to *all* those which touch upon its borders. Hence any *linear* arrangement of the orders must be in some degree artificial.

894. **One natural system.** Although there be but one truly natural system, yet while any portion of it remains imperfectly understood, so far authors may be expected to hold different views, and to attempt by different methods to express that true system. Still the discrepancies observed in the several "Natural Systems," proposed by different writers, are slight compared with the number and importance of the principles now common to them all and universally admitted.

895. **The first and highest division** of the Vegetable Kingdom, viz., into the Phænogamia or Flowering Plants, and the Cryptogamia or Flowerless Plants, has already been noticed and defined. These grand divisions, or sub-kingdoms, lie at the foundation of both the systems of Linnæus and of Jussieu, and have in substance been adopted by every subsequent author. It is a division founded in nature, that is, marked by nature herself, for

The **Phænogamia** (*φαίνω*, to appear, *γάμος*, nuptials),
- *a*, Consist of a regular axis of growth with leafy appendages,
- *b*, They possess a woody and spiro-vascular structure,
- *c*, They develop stamens and pistils constituting flowers.
- *d*, They produce seeds containing an embryo. On the other hand

The **Cryptogamia** (*κρύπτω*, to conceal, *γάμος*).
- *a*, Are generally destitute of a regular axis and of true leaves,
- *b*, They possess mostly a cellular structure only,
- *c*, They do not develop true flowers,
- *d*, They produce spores having no embryo.

896. **Natural divisions indefinite.** The above diagnosis does not mark the absolute limits between the two sub-kingdoms, for the higher Cryptogamia, as the mosses and ferns, give indications of approach to the Phænogamia, both in form and structure, while the lower Phænogamia can scarcely be said to produce flowers. And universally, so gradual is the transition from group to group, that it is difficult

or impossible to fix upon characters so definite as to circumscribe completely any one group, while at the same time they exclude every member of the surrounding allied groups.

897. Second division. The Flowering plants are next resolved into two great *provinces*, indubitably marked by nature's own hand, and employed in every natural method. The following is their diagnosis.

Exogenæ (*ἔξω*, without, *γεννάω*, to generate), or Dicotyledonous Plants.
a, Growing by layers external to the wood, internal to the bark,
b, Leaves net-veined,
c, Flowers 4 or 5-parted, rarely 3-parted,
d, Seeds with two or more cotyledons, and
e, The radicle producing an axial root.

Endogenæ, (*ἔνδον*, within, *γεννάω*), or Monocotyledonous Plants.
a, Growing by scattered internal wood-bundles,
b, Leaves parallel-veined,
c, Flowers very generally 3-parted,
d, Seeds with one cotyledon, and
e, The radicle never producing an axial root.

898. Third division;—classes. The provinces are next broken into classes—groups of the third rank in extent. Two are constituted of the Exogens, viz.:

Angiospermæ (*αγγε͂ιος*, a vessel, *σπέρμα*, seed) (oak, rose).
a, Flowers more generally perfect or complete,
b, Pistils complete, inclosing the ovules,
c, Seeds inclosed in a pericarp.
d, Embryo with only two cotyledons.

Gymnospermæ (*γυμνὸς*, naked, *σπέρμα*) (pine, yew).
a, Flowers imperfect and incomplete,
b, Pistils scale-like, without a stigma,
c, Seeds truly naked, that is, destitute of a pericarp,
d, Embryo mostly with several whorled cotyledons.

Two classes are formed from the Endogens, viz.:

Petaliferæ (*πέταλον*, petal, *φέρω*, to bear).

Plants of the endogenous structure, with flowers constructed on the usual plan; perianth of one or more whorls of petaloid organs, or wanting (lily, Orchis, rush).

Glumiferæ (*gluma*, husk, *fero*, to bear).

Plants of the endogenous structure, the flowers invested with an imbricated perianth of glumes, instead of petals and sepals (grasses, grains, sedges).

899. Divisions of the cryptogamia. This sub-kingdom is naturally divided into two provinces, the Acrogens, and Thallogens,—terms founded upon their mode of vegetation. The former include those tribes which make some approximation towards the Phænogamia, the latter include the lowest tribes in the vegetable kingdom.

Acrogenæ (*ἄκρον*, the summit, *γεννάω*).

Flowerless plants having a regular stem or axis, which grows by the extension of the apex only, without increasing at all in diameter, generally with leaves, and composed of cellular tissue and scalariform ducts (Ferns, mosses, club-mosses, horsetails, etc.)

THALLOGENÆ (θάλλος, green branch, γεννάω).

Flowerless plants producing in vegetation a *thallus*, with no distinction of stem and leaf, or root, and composed of cellular tissue only (Lichens, fungi, etc.)

900. **CLASSES OF THE FLOWERLESS PLANTS.** For the sake of analogy and an advantageous comparison with the Phænogams, we may also regard these two provinces of the Cryptogams in the light of Classes founded upon their different modes of fruitbearing. Thus the Acrogens constitute the class

ANGIOSPORÆ (αγγεῖος, σπορὰ).

Acrogenous plants, producing their spores in sporangia (vessels) which burst when the spores are mature.

GYMNOSPORÆ (γυμνὸς, σπορὰ).

Thallogenous plants reproduced by spores, which are produced in parent cells, either forming a part of the vegetating thallus, or growing upon the surface of some definite region of the thallus.

901. **FOURTH DIVISION—COHORTS.** The six classes, as above constituted, are still each of great extent,—too great for the comprehension of the learner, or practical use. A further division is therefore necessary. To effect this on strictly natural principles botanists have labored hitherto in vain. The truth is, the members of these several classes are united by affinities so equable as to render it impossible to subdivide, except by distinctions more or less arbitrary. So adjacent territories, where rivers or other natural boundaries are wanting, must be separated by artificial lines.

902. **THE ANGIOSPERMS ARE DIVIDED BY DE CANDOLLE,** in his great descriptive work "Prodromus Systematis Naturalis Regni Vegetabilis" into four sub-classes founded upon the conditions of the floral envelops, viz.:

1. *Thalamifloræ*, petals distinct, and (with the stamens) hypogynous.
2. *Calycifloræ*, petals (with the stamens) perigynous.
3. *Corollifloræ*, petals united, hypogynous, stamens epipetalous.
4. *Monochlamydeæ*, petals wanting.

903. **THE PLAN OF ENDLICHER** in his "Genera Plantarum" is more simple and convenient, and has been followed by American writers generally. He separates the Angiospermæ into three "cohorts," thus:

1. *Dialypetalæ* (διαλύω, to dissolve). Exogenous plants, having both calyx and corolla, the latter composed of distinct petals (polypetalous), sometimes slightly cohering by the base of the stamens, rarely abortive.
2. *Gamopetalæ* (γαμός, union). Exogenous plants, having both calyx and corolla, the latter composed of petals more or less united.
3. *Apetalæ* (α, privative). Exogenous plants with flowers having a calyx only, or neither calyx nor corolla (achlamydeous).

904. **THE CLASS PETALIFERÆ** may be conveniently separated into two cohorts, as follows.

1. *Spadicifloræ*. Endogenous plants with flowers having no perianth, or a scaly one, and borne on a thickened spadix, which is often enveloped in a spathe.

2. *Floridea.* Endogenous plants with the flowers usually perfect and complete, the perianth double, 3-parted, the outer often and sometimes both green.

905. THE CLASS GLUMIFERÆ is equivalent to the cohort *Graminoideæ*, including the sedges, grains, and grasses—a truly natural assemblage.

906. THE CLASS ANGIOSPORA consists of three cohorts defined as follows.

1. *Sporogamia.* Angiósporous plants, producing spores in which, when germinating, anthiridial cells and archegonal, or ovulary bodies, are found (Lycopodiaceæ, Isoetaceæ, Marsileaceæ).
2. *Thallogamia.* Angiosporous plants producing spores of one kind in sporanges on the surface of the leaf or stem, the spore germinating into a green *prothallus* (629) on which are developed antheridia and archegonia, the latter giving origin to a leafy embryo (Equisetaceæ, Filices).
3. *Axogamia.* Angiosporous plants producing antheridia and archegonia in the axils of the leaves or in buds, the fertilized archegonia giving birth to sporanges filled with spores, all reproducing the plant (Mosses, Hepaticæ, Characeæ).

907. THE CLASS GYMNOSPORÆ consists of three cohorts, viz.:

1. *Aerophyta.* Thallogens growing and fructifying in the air, reproduced by spores formed in *asci*, and by green gonidia formed in the medullary layer of the thallus (Lichens).
2. *Hysterophyta.* Thallogens growing in or on decaying organic substances and fructifying in the open air, destitute of chlorophylle and starch, reproduced by spores formed in asci, by archegonal spores and by gonidea (Fungi).
3. *Hydrophyta.* Thallogens with a branching or foliaceous thallus; membranous, gelatinous, or cartilaginous in texture, containing either chlorophylle or a red coloring matter and often starch grains; growing in water, salt or fresh, or in moist substances in damp air (Algæ).

908. THE FOLLOWING SYNOPTICAL ARRANGEMENT of the above divisions and subdivisions will exhibit at a glance the relative position and mutual relations of each.

THE VEGETABLE KINGDOM.

The sub-kingdom, PHÆNOGAMIA, or FLOWERING PLANTS.
  Province 1st. *Exogenæ*, or *Dicotyledons.*
    Class I. Angiospermæ.
      Cohort 1. Dialypetalæ, or Polypetalæ.
      Cohort 2. Gamopetalæ, or Monopetalæ.
      Cohort 3. Apetalæ, or Monochamydeæ.
    Class II. Gymnospermæ.
      Cohort 4. Conoideæ.
  Province 2. *Endogenæ*, or *Monocotyledons.*
    Class III. Petaliferæ, or Algumaceæ.
      Cohort 5. Spadicifloræ (Aroideæ, etc.)

- Cohort 6. Florideæ (Liliaceæ, etc.)
- Class IV. Glumiferæ, or Glumaceæ.
  - Cohort 7. Graminoideæ (Sedges, grasses).

The sub-kingdom CRYPTOGAMIA, or FLOWERLESS PLANTS.

- Province 3. *Acrogenæ.*
  - Class V. Angiosporæ.
    - Cohort 8. Sporogamia (Marsilleaceæ, Lycopodiaceæ).
    - Cohort 9. Thallogamia (Filices, etc.)
    - Cohort 10. Axogamia (Mosses and Hepaticæ).
- Province 4. *Thallogenæ.*
  - Class VI. Gymnosporæ.
    - Cohort 11. Aerophyta (Lichens).
    - Cohort 12. Hysterophyta (Fungi).
    - Cohort 13. Hydrophyta (Algæ).